GNU Awk

GAWK: Effective AWK Programming

A User's Guide for GNU Awk
Edition 4.1
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This is Edition 4.1 of *GAWK: Effective AWK Programming: A User's Guide for GNU Awk*, for the 4.1.0 (or later) version of the GNU implementation of AWK.

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b. "You have the freedom to copy and modify this GNU manual. Buying copies from the FSF supports it in developing GNU and promoting software freedom."

To Miriam, for making me complete.

To Chana, for the joy you bring us.

To Rivka, for the exponential increase.

To Nachum, for the added dimension.

To Malka, for the new beginning.

Short Contents

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Foreword

Arnold Robbins and I are good friends. We were introduced in 1990 by circumstances—and our favorite programming language, AWK. The circumstances started a couple of years earlier. I was working at a new job and noticed an unplugged Unix computer sitting in the corner. No one knew how to use it, and neither did I. However, a couple of days later it was running, and I was `root` and the one-and-only user. That day, I began the transition from statistician to Unix programmer.

On one of many trips to the library or bookstore in search of books on Unix, I found the gray AWK book, a.k.a. Aho, Kernighan and Weinberger, *The AWK Programming Language*, Addison-Wesley, 1988. AWK's simple programming paradigm—find a pattern in the input and then perform an action—often reduced complex or tedious data manipulations to few lines of code. I was excited to try my hand at programming in AWK.

Alas, the `awk` on my computer was a limited version of the language described in the AWK book. I discovered that my computer had "old `awk`" and the AWK book described "new `awk`." I learned that this was typical; the old version refused to step aside or relinquish its name. If a system had a new `awk`, it was invariably called `nawk`, and few systems had it. The best way to get a new `awk` was to `ftp` the source code for `gawk` from `prep.ai.mit.edu`. `gawk` was a version of new `awk` written by David Trueman and Arnold, and available under the GNU General Public License.

(Incidentally, it's no longer difficult to find a new `awk`. `gawk` ships with GNU/Linux, and you can download binaries or source code for almost any system; my wife uses `gawk` on her VMS box.)

My Unix system started out unplugged from the wall; it certainly was not plugged into a network. So, oblivious to the existence of `gawk` and the Unix community in general, and desiring a new `awk`, I wrote my own, called `mawk`. Before I was finished I knew about `gawk`, but it was too late to stop, so I eventually posted to a `comp.sources` newsgroup.

A few days after my posting, I got a friendly email from Arnold introducing himself. He suggested we share design and algorithms and attached a draft of the POSIX standard so that I could update `mawk` to support language extensions added after publication of the AWK book.

Frankly, if our roles had been reversed, I would not have been so open and we probably would have never met. I'm glad we did meet. He is an AWK expert's AWK expert and a genuinely nice person. Arnold contributes significant amounts of his expertise and time to the Free Software Foundation.

This book is the `gawk` reference manual, but at its core it is a book about AWK programming that will appeal to a wide audience. It is a definitive reference to the AWK language as defined by the 1987 Bell Laboratories release and codified in the 1992 POSIX Utilities standard.

On the other hand, the novice AWK programmer can study a wealth of practical programs that emphasize the power of AWK's basic idioms: data driven control-flow, pattern matching with regular expressions, and associative arrays. Those looking for something new can try out `gawk`'s interface to network protocols via special `/inet` files.

The programs in this book make clear that an AWK program is typically much smaller and faster to develop than a counterpart written in C. Consequently, there is often a payoff to prototype an algorithm or design in AWK to get it running quickly and expose problems early. Often, the interpreted performance is adequate and the AWK prototype becomes the product.

The new `pgawk` (profiling `gawk`), produces program execution counts. I recently experimented with an algorithm that for n lines of input, exhibited $\sim Cn^2$ performance, while theory predicted $\sim Cn \log n$ behavior. A few minutes poring over the `awkprof.out` profile pinpointed the problem to a single line of code. `pgawk` is a welcome addition to my programmer's toolbox.

Arnold has distilled over a decade of experience writing and using AWK programs, and developing `gawk`, into this book. If you use AWK or want to learn how, then read this book.

Michael Brennan
Author of `mawk`
March, 2001

Preface

Several kinds of tasks occur repeatedly when working with text files. You might want to extract certain lines and discard the rest. Or you may need to make changes wherever certain patterns appear, but leave the rest of the file alone. Writing single-use programs for these tasks in languages such as C, C++, or Java is time-consuming and inconvenient. Such jobs are often easier with `awk`. The `awk` utility interprets a special-purpose programming language that makes it easy to handle simple data-reformatting jobs.

The GNU implementation of `awk` is called `gawk`; if you invoke it with the proper options or environment variables (see Section 2.2 [Command-Line Options], page 29), it is fully compatible with the POSIX[1] specification of the `awk` language and with the Unix version of `awk` maintained by Brian Kernighan. This means that all properly written `awk` programs should work with `gawk`. Thus, we usually don't distinguish between `gawk` and other `awk` implementations.

Using `awk` allows you to:

- Manage small, personal databases
- Generate reports
- Validate data
- Produce indexes and perform other document preparation tasks
- Experiment with algorithms that you can adapt later to other computer languages

In addition, `gawk` provides facilities that make it easy to:

- Extract bits and pieces of data for processing
- Sort data
- Perform simple network communications

This book teaches you about the `awk` language and how you can use it effectively. You should already be familiar with basic system commands, such as `cat` and `ls`,[2] as well as basic shell facilities, such as input/output (I/O) redirection and pipes.

Implementations of the `awk` language are available for many different computing environments. This book, while describing the `awk` language in general, also describes the particular implementation of `awk` called `gawk` (which stands for "GNU awk"). `gawk` runs on a broad range of Unix systems, ranging from Intel®-architecture PC-based computers up through large-scale systems, such as Crays. `gawk` has also been ported to Mac OS X, Microsoft Windows (all versions) and OS/2 PCs, and VMS. (Some other, obsolete systems to which `gawk` was once ported are no longer supported and the code for those systems has been removed.)

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[1] The 2008 POSIX standard is online at `http://www.opengroup.org/onlinepubs/9699919799/`.

[2] These commands are available on POSIX-compliant systems, as well as on traditional Unix-based systems. If you are using some other operating system, you still need to be familiar with the ideas of I/O redirection and pipes.

History of awk and gawk

Recipe For A Programming Language

1 part egrep	1 part snobol
2 parts ed	3 parts C

Blend all parts well using lex and yacc. Document minimally and release.

After eight years, add another part egrep and two more parts C. Document very well and release.

The name awk comes from the initials of its designers: Alfred V. Aho, Peter J. Weinberger and Brian W. Kernighan. The original version of awk was written in 1977 at AT&T Bell Laboratories. In 1985, a new version made the programming language more powerful, introducing user-defined functions, multiple input streams, and computed regular expressions. This new version became widely available with Unix System V Release 3.1 (1987). The version in System V Release 4 (1989) added some new features and cleaned up the behavior in some of the "dark corners" of the language. The specification for awk in the POSIX Command Language and Utilities standard further clarified the language. Both the gawk designers and the original Bell Laboratories awk designers provided feedback for the POSIX specification.

Paul Rubin wrote the GNU implementation, gawk, in 1986. Jay Fenlason completed it, with advice from Richard Stallman. John Woods contributed parts of the code as well. In 1988 and 1989, David Trueman, with help from me, thoroughly reworked gawk for compatibility with the newer awk. Circa 1994, I became the primary maintainer. Current development focuses on bug fixes, performance improvements, standards compliance, and occasionally, new features.

In May of 1997, Jürgen Kahrs felt the need for network access from awk, and with a little help from me, set about adding features to do this for gawk. At that time, he also wrote the bulk of *TCP/IP Internetworking with* gawk (a separate document, available as part of the gawk distribution). His code finally became part of the main gawk distribution with gawk version 3.1.

John Haque rewrote the gawk internals, in the process providing an awk-level debugger. This version became available as gawk version 4.0, in 2011.

See Section A.8 [Major Contributors to gawk], page 395, for a complete list of those who made important contributions to gawk.

A Rose by Any Other Name

The awk language has evolved over the years. Full details are provided in Appendix A [The Evolution of the awk Language], page 389. The language described in this book is often referred to as "new awk" (nawk).

Because of this, there are systems with multiple versions of awk. Some systems have an awk utility that implements the original version of the awk language and a nawk utility for the new version. Others have an oawk version for the "old awk" language and plain awk for the new one. Still others only have one version, which is usually the new one.[3]

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[3] Often, these systems use gawk for their awk implementation!

All in all, this makes it difficult for you to know which version of `awk` you should run when writing your programs. The best advice we can give here is to check your local documentation. Look for `awk`, `oawk`, and `nawk`, as well as for `gawk`. It is likely that you already have some version of new `awk` on your system, which is what you should use when running your programs. (Of course, if you're reading this book, chances are good that you have `gawk`!)

Throughout this book, whenever we refer to a language feature that should be available in any complete implementation of POSIX `awk`, we simply use the term `awk`. When referring to a feature that is specific to the GNU implementation, we use the term `gawk`.

Using This Book

The term `awk` refers to a particular program as well as to the language you use to tell this program what to do. When we need to be careful, we call the language "the `awk` language," and the program "the `awk` utility." This book explains both how to write programs in the `awk` language and how to run the `awk` utility. The term `awk` *program* refers to a program written by you in the `awk` programming language.

Primarily, this book explains the features of `awk` as defined in the POSIX standard. It does so in the context of the `gawk` implementation. While doing so, it also attempts to describe important differences between `gawk` and other `awk` implementations.[4] Finally, any `gawk` features that are not in the POSIX standard for `awk` are noted.

This book has the difficult task of being both a tutorial and a reference. If you are a novice, feel free to skip over details that seem too complex. You should also ignore the many cross-references; they are for the expert user and for the online Info and HTML versions of the document.

There are sidebars scattered throughout the book. They add a more complete explanation of points that are relevant, but not likely to be of interest on first reading. All appear in the index, under the heading "sidebar."

Most of the time, the examples use complete `awk` programs. Some of the more advanced sections show only the part of the `awk` program that illustrates the concept currently being described.

While this book is aimed principally at people who have not been exposed to `awk`, there is a lot of information here that even the `awk` expert should find useful. In particular, the description of POSIX `awk` and the example programs in Chapter 10 [A Library of `awk` Functions], page 201, and in Chapter 11 [Practical `awk` Programs], page 231, should be of interest.

This book is split into several parts, as follows:

Part I describes the `awk` language and `gawk` program in detail. It starts with the basics, and continues through all of the features of `awk`. It contains the following chapters:

Chapter 1 [Getting Started with `awk`], page 15, provides the essentials you need to know to begin using `awk`.

Chapter 2 [Running `awk` and `gawk`], page 29, describes how to run `gawk`, the meaning of its command-line options, and how it finds `awk` program source files.

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[4] All such differences appear in the index under the entry "differences in `awk` and `gawk`."

Chapter 3 [Regular Expressions], page 43, introduces regular expressions in general, and in particular the flavors supported by POSIX awk and gawk.

Chapter 4 [Reading Input Files], page 55, describes how awk reads your data. It introduces the concepts of records and fields, as well as the getline command. I/O redirection is first described here. Network I/O is also briefly introduced here.

Chapter 5 [Printing Output], page 81, describes how awk programs can produce output with print and printf.

Chapter 6 [Expressions], page 97, describes expressions, which are the basic building blocks for getting most things done in a program.

Chapter 7 [Patterns, Actions, and Variables], page 119, describes how to write patterns for matching records, actions for doing something when a record is matched, and the built-in variables awk and gawk use.

Chapter 8 [Arrays in awk], page 145, covers awk's one-and-only data structure: associative arrays. Deleting array elements and whole arrays is also described, as well as sorting arrays in gawk. It also describes how gawk provides arrays of arrays.

Chapter 9 [Functions], page 159, describes the built-in functions awk and gawk provide, as well as how to define your own functions.

Part II shows how to use awk and gawk for problem solving. There is lots of code here for you to read and learn from. It contains the following chapters:

Chapter 10 [A Library of awk Functions], page 201, which provides a number of functions meant to be used from main awk programs.

Chapter 11 [Practical awk Programs], page 231, which provides many sample awk programs.

Reading these two chapters allows you to see awk solving real problems.

Part III focuses on features specific to gawk. It contains the following chapters:

Chapter 12 [Advanced Features of gawk], page 277, describes a number of gawk-specific advanced features. Of particular note are the abilities to have two-way communications with another process, perform TCP/IP networking, and profile your awk programs.

Chapter 13 [Internationalization with gawk], page 291, describes special features in gawk for translating program messages into different languages at runtime.

Chapter 14 [Debugging awk Programs], page 301, describes the awk debugger.

Chapter 15 [Arithmetic and Arbitrary Precision Arithmetic with gawk], page 317, describes advanced arithmetic facilities provided by gawk.

Chapter 16 [Writing Extensions for gawk], page 333, describes how to add new variables and functions to gawk by writing extensions in C or C++.

Part IV provides the appendices, the Glossary, and two licenses that cover the gawk source code and this book, respectively. It contains the following appendices:

Appendix A [The Evolution of the awk Language], page 389, describes how the awk language has evolved since its first release to present. It also describes how gawk has acquired features over time.

Appendix B [Installing gawk], page 399, describes how to get gawk, how to compile it on POSIX-compatible systems, and how to compile and use it on different non-POSIX systems.

It also describes how to report bugs in `gawk` and where to get other freely available `awk` implementations.

Appendix C [Implementation Notes], page 415, describes how to disable `gawk`'s extensions, as well as how to contribute new code to `gawk`, and some possible future directions for `gawk` development.

Appendix D [Basic Programming Concepts], page 425, provides some very cursory background material for those who are completely unfamiliar with computer programming.

The [Glossary], page 429, defines most, if not all, the significant terms used throughout the book. If you find terms that you aren't familiar with, try looking them up here.

[GNU General Public License], page 439, and [GNU Free Documentation License], page 451, present the licenses that cover the `gawk` source code and this book, respectively.

Typographical Conventions

This book is written in Texinfo (`http://www.gnu.org/software/texinfo/`), the GNU documentation formatting language. A single Texinfo source file is used to produce both the printed and online versions of the documentation. Because of this, the typographical conventions are slightly different than in other books you may have read.

Examples you would type at the command-line are preceded by the common shell primary and secondary prompts, '`$`' and '`>`'. Input that you type is shown *`like this`*. Output from the command is preceded by the glyph "⊣". This typically represents the command's standard output. Error messages, and other output on the command's standard error, are preceded by the glyph "error". For example:

```
$ echo hi on stdout
⊣ hi on stdout
$ echo hello on stderr 1>&2
error  hello on stderr
```

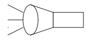
In the text, command names appear in `this font`, while code segments appear in the same font and quoted, '`like this`'. Options look like this: `-f`. Some things are emphasized *like this*, and if a point needs to be made strongly, it is done **like this**. The first occurrence of a new term is usually its *definition* and appears in the same font as the previous occurrence of "definition" in this sentence. Finally, file names are indicated like this: `/path/to/ourfile`.

Characters that you type at the keyboard look *`like this`*. In particular, there are special characters called "control characters." These are characters that you type by holding down both the *`CONTROL`* key and another key, at the same time. For example, a *`Ctrl-d`* is typed by first pressing and holding the *`CONTROL`* key, next pressing the *`d`* key and finally releasing both keys.

Dark Corners

Dark corners are basically fractal — no matter how much you illuminate, there's always a smaller but darker one.
Brian Kernighan

Until the POSIX standard (and *GAWK: Effective AWK Programming*), many features of `awk` were either poorly documented or not documented at all. Descriptions of such features (often called "dark corners") are noted in this book with the picture of a flashlight in the margin, as shown here. They also appear in the index under the heading "dark corner."



As noted by the opening quote, though, any coverage of dark corners is, by definition, incomplete.

Extensions to the standard `awk` language that are supported by more than one `awk` implementation are marked "(c.e.)," and listed in the index under "common extensions" and "extensions, common."

The GNU Project and This Book

The Free Software Foundation (FSF) is a nonprofit organization dedicated to the production and distribution of freely distributable software. It was founded by Richard M. Stallman, the author of the original Emacs editor. GNU Emacs is the most widely used version of Emacs today.

The GNU[5] Project is an ongoing effort on the part of the Free Software Foundation to create a complete, freely distributable, POSIX-compliant computing environment. The FSF uses the "GNU General Public License" (GPL) to ensure that their software's source code is always available to the end user. A copy of the GPL is included in this book for your reference (see [GNU General Public License], page 439). The GPL applies to the C language source code for `gawk`. To find out more about the FSF and the GNU Project online, see the GNU Project's home page (`http://www.gnu.org`). This book may also be read from their web site (`http://www.gnu.org/software/gawk/manual/`).

A shell, an editor (Emacs), highly portable optimizing C, C++, and Objective-C compilers, a symbolic debugger and dozens of large and small utilities (such as `gawk`), have all been completed and are freely available. The GNU operating system kernel (the HURD), has been released but remains in an early stage of development.

Until the GNU operating system is more fully developed, you should consider using GNU/Linux, a freely distributable, Unix-like operating system for Intel®, Power Architecture, Sun SPARC, IBM S/390, and other systems.[6] Many GNU/Linux distributions are available for download from the Internet.

(There are numerous other freely available, Unix-like operating systems based on the Berkeley Software Distribution, and some of them use recent versions of `gawk` for their versions of `awk`. NetBSD (`http://www.netbsd.org`), FreeBSD (`http://www.freebsd.org`), and OpenBSD (`http://www.openbsd.org`) are three of the most popular ones, but there are others.)

The book you are reading is actually free—at least, the information in it is free to anyone. The machine-readable source code for the book comes with `gawk`; anyone may take this book to a copying machine and make as many copies as they like. (Take a moment to check the Free Documentation License in [GNU Free Documentation License], page 451.)

The book itself has gone through a number of previous editions. Paul Rubin wrote the very first draft of *The GAWK Manual*; it was around 40 pages in size. Diane Close and Richard Stallman improved it, yielding a version that was around 90 pages long and barely described the original, "old" version of `awk`.

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[5] GNU stands for "GNU's not Unix."

[6] The terminology "GNU/Linux" is explained in the [Glossary], page 429.

I started working with that version in the fall of 1988. As work on it progressed, the FSF published several preliminary versions (numbered 0.*x*). In 1996, Edition 1.0 was released with `gawk` 3.0.0. The FSF published the first two editions under the title *The GNU Awk User's Guide*.

This edition maintains the basic structure of the previous editions. For Edition 4.0, the content has been thoroughly reviewed and updated. All references to `gawk` versions prior to 4.0 have been removed. Of significant note for this edition was Chapter 14 [Debugging `awk` Programs], page 301.

For edition 4.1, the content has been reorganized into parts, and the major new additions are Chapter 15 [Arithmetic and Arbitrary Precision Arithmetic with `gawk`], page 317, and Chapter 16 [Writing Extensions for `gawk`], page 333.

GAWK: Effective AWK Programming will undoubtedly continue to evolve. An electronic version comes with the `gawk` distribution from the FSF. If you find an error in this book, please report it! See Section B.4 [Reporting Problems and Bugs], page 410, for information on submitting problem reports electronically.

How to Contribute

As the maintainer of GNU `awk`, I once thought that I would be able to manage a collection of publicly available `awk` programs and I even solicited contributions. Making things available on the Internet helps keep the `gawk` distribution down to manageable size.

The initial collection of material, such as it is, is still available at `ftp://ftp.freefriends.org/arnold/Awkstuff`. In the hopes of doing something more broad, I acquired the `awk.info` domain.

However, I found that I could not dedicate enough time to managing contributed code: the archive did not grow and the domain went unused for several years.

Fortunately, late in 2008, a volunteer took on the task of setting up an `awk`-related web site—`http://awk.info`—and did a very nice job.

If you have written an interesting `awk` program, or have written a `gawk` extension that you would like to share with the rest of the world, please see `http://awk.info/?contribute` for how to contribute it to the web site.

Acknowledgments

The initial draft of *The GAWK Manual* had the following acknowledgments:

> Many people need to be thanked for their assistance in producing this manual. Jay Fenlason contributed many ideas and sample programs. Richard Mlynarik and Robert Chassell gave helpful comments on drafts of this manual. The paper *A Supplemental Document for* `awk` by John W. Pierce of the Chemistry Department at UC San Diego, pinpointed several issues relevant both to `awk` implementation and to this manual, that would otherwise have escaped us.

I would like to acknowledge Richard M. Stallman, for his vision of a better world and for his courage in founding the FSF and starting the GNU Project.

Earlier editions of this book had the following acknowledgements:

> The following people (in alphabetical order) provided helpful comments on various versions of this book, Rick Adams, Dr. Nelson H.F. Beebe, Karl Berry,

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>
> Robert J. Chassell provided much valuable advice on the use of Texinfo. He also deserves special thanks for convincing me *not* to title this book *How To Gawk Politely*. Karl Berry helped significantly with the TeX part of Texinfo.
>
> I would like to thank Marshall and Elaine Hartholz of Seattle and Dr. Bert and Rita Schreiber of Detroit for large amounts of quiet vacation time in their homes, which allowed me to make significant progress on this book and on `gawk` itself.
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> Phil Hughes of SSC contributed in a very important way by loaning me his laptop GNU/Linux system, not once, but twice, which allowed me to do a lot of work while away from home.
>
> David Trueman deserves special credit; he has done a yeoman job of evolving `gawk` so that it performs well and without bugs. Although he is no longer involved with `gawk`, working with him on this project was a significant pleasure.
>
> The intrepid members of the GNITS mailing list, and most notably Ulrich Drepper, provided invaluable help and feedback for the design of the internationalization features.
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Dr. Nelson Beebe, Andreas Buening, Dr. Manuel Collado, Antonio Colombo, Stephen Davies, Scott Deifik, Akim Demaille, Darrel Hankerson, Michal Jaegermann, Jürgen Kahrs, Stepan Kasal, John Malmberg, Dave Pitts, Chet Ramey, Pat Rankin, Andrew Schorr, Corinna Vinschen, Anders Wallin, and Eli Zaretskii (in alphabetical order) make up the current `gawk` "crack portability team." Without their hard work and help, `gawk` would not be nearly the fine program it is today. It has been and continues to be a pleasure working with this team of fine people.

Notable code and documentation contributions were made by a number of people. See Section A.8 [Major Contributors to `gawk`], page 395, for the full list.

I would like to thank Brian Kernighan for invaluable assistance during the testing and debugging of `gawk`, and for ongoing help and advice in clarifying numerous points about the language. We could not have done nearly as good a job on either `gawk` or its documentation without his help.

I must thank my wonderful wife, Miriam, for her patience through the many versions of this project, for her proofreading, and for sharing me with the computer. I would like to thank my parents for their love, and for the grace with which they raised and educated me. Finally, I also must acknowledge my gratitude to G-d, for the many opportunities He has sent my way, as well as for the gifts He has given me with which to take advantage of those opportunities.

Arnold Robbins
Nof Ayalon

ISRAEL
May, 2013

Part I:
The awk Language

1 Getting Started with awk

The basic function of awk is to search files for lines (or other units of text) that contain certain patterns. When a line matches one of the patterns, awk performs specified actions on that line. awk keeps processing input lines in this way until it reaches the end of the input files.

Programs in awk are different from programs in most other languages, because awk programs are *data-driven*; that is, you describe the data you want to work with and then what to do when you find it. Most other languages are *procedural*; you have to describe, in great detail, every step the program is to take. When working with procedural languages, it is usually much harder to clearly describe the data your program will process. For this reason, awk programs are often refreshingly easy to read and write.

When you run awk, you specify an awk *program* that tells awk what to do. The program consists of a series of *rules*. (It may also contain *function definitions*, an advanced feature that we will ignore for now. See Section 9.2 [User-Defined Functions], page 184.) Each rule specifies one pattern to search for and one action to perform upon finding the pattern.

Syntactically, a rule consists of a pattern followed by an action. The action is enclosed in curly braces to separate it from the pattern. Newlines usually separate rules. Therefore, an awk program looks like this:

```
pattern { action }
pattern { action }
...
```

1.1 How to Run awk Programs

There are several ways to run an awk program. If the program is short, it is easiest to include it in the command that runs awk, like this:

```
awk 'program' input-file1 input-file2 ...
```

When the program is long, it is usually more convenient to put it in a file and run it with a command like this:

```
awk -f program-file input-file1 input-file2 ...
```

This section discusses both mechanisms, along with several variations of each.

1.1.1 One-Shot Throwaway awk Programs

Once you are familiar with awk, you will often type in simple programs the moment you want to use them. Then you can write the program as the first argument of the awk command, like this:

```
awk 'program' input-file1 input-file2 ...
```

where *program* consists of a series of *patterns* and *actions*, as described earlier.

This command format instructs the *shell*, or command interpreter, to start awk and use the *program* to process records in the input file(s). There are single quotes around *program* so the shell won't interpret any awk characters as special shell characters. The quotes also cause the shell to treat all of *program* as a single argument for awk, and allow *program* to be more than one line long.

This format is also useful for running short or medium-sized `awk` programs from shell scripts, because it avoids the need for a separate file for the `awk` program. A self-contained shell script is more reliable because there are no other files to misplace.

Section 1.3 [Some Simple Examples], page 21, later in this chapter, presents several short, self-contained programs.

1.1.2 Running awk Without Input Files

You can also run `awk` without any input files. If you type the following command line:

```
awk 'program'
```

`awk` applies the *program* to the *standard input*, which usually means whatever you type on the terminal. This continues until you indicate end-of-file by typing *Ctrl-d*. (On other operating systems, the end-of-file character may be different. For example, on OS/2, it is *Ctrl-z*.)

As an example, the following program prints a friendly piece of advice (from Douglas Adams's *The Hitchhiker's Guide to the Galaxy*), to keep you from worrying about the complexities of computer programming[1] (`BEGIN` is a feature we haven't discussed yet):

```
$ awk "BEGIN { print \"Don't Panic!\" }"
⊣ Don't Panic!
```

This program does not read any input. The '\' before each of the inner double quotes is necessary because of the shell's quoting rules—in particular because it mixes both single quotes and double quotes.[2]

This next simple `awk` program emulates the `cat` utility; it copies whatever you type on the keyboard to its standard output (why this works is explained shortly).

```
$ awk '{ print }'
Now is the time for all good men
⊣ Now is the time for all good men
to come to the aid of their country.
⊣ to come to the aid of their country.
Four score and seven years ago, ...
⊣ Four score and seven years ago, ...
What, me worry?
⊣ What, me worry?
Ctrl-d
```

1.1.3 Running Long Programs

Sometimes your `awk` programs can be very long. In this case, it is more convenient to put the program into a separate file. In order to tell `awk` to use that file for its program, you type:

```
awk -f source-file input-file1 input-file2 ...
```

---

[1] If you use Bash as your shell, you should execute the command '`set +H`' before running this program interactively, to disable the C shell-style command history, which treats '`!`' as a special character. We recommend putting this command into your personal startup file.

[2] Although we generally recommend the use of single quotes around the program text, double quotes are needed here in order to put the single quote into the message.

The -f instructs the awk utility to get the awk program from the file *source-file*. Any file name can be used for *source-file*. For example, you could put the program:

```
BEGIN { print "Don't Panic!" }
```

into the file advice. Then this command:

```
awk -f advice
```

does the same thing as this one:

```
awk "BEGIN { print \"Don't Panic!\" }"
```

This was explained earlier (see Section 1.1.2 [Running awk Without Input Files], page 16). Note that you don't usually need single quotes around the file name that you specify with -f, because most file names don't contain any of the shell's special characters. Notice that in advice, the awk program did not have single quotes around it. The quotes are only needed for programs that are provided on the awk command line.

If you want to clearly identify your awk program files as such, you can add the extension .awk to the file name. This doesn't affect the execution of the awk program but it does make "housekeeping" easier.

1.1.4 Executable awk Programs

Once you have learned awk, you may want to write self-contained awk scripts, using the '#!' script mechanism. You can do this on many systems.[3] For example, you could update the file advice to look like this:

```
#! /bin/awk -f

BEGIN { print "Don't Panic!" }
```

After making this file executable (with the chmod utility), simply type 'advice' at the shell and the system arranges to run awk[4] as if you had typed 'awk -f advice':

```
$ chmod +x advice
$ advice
⊣ Don't Panic!
```

(We assume you have the current directory in your shell's search path variable [typically $PATH]. If not, you may need to type './advice' at the shell.)

Self-contained awk scripts are useful when you want to write a program that users can invoke without their having to know that the program is written in awk.

[3] The '#!' mechanism works on GNU/Linux systems, BSD-based systems and commercial Unix systems.

[4] The line beginning with '#!' lists the full file name of an interpreter to run and an optional initial command-line argument to pass to that interpreter. The operating system then runs the interpreter with the given argument and the full argument list of the executed program. The first argument in the list is the full file name of the awk program. The rest of the argument list contains either options to awk, or data files, or both. Note that on many systems awk may be found in /usr/bin instead of in /bin. Caveat Emptor.

Portability Issues with '#!'

Some systems limit the length of the interpreter name to 32 characters. Often, this can be dealt with by using a symbolic link.

You should not put more than one argument on the '#!' line after the path to awk. It does not work. The operating system treats the rest of the line as a single argument and passes it to awk. Doing this leads to confusing behavior—most likely a usage diagnostic of some sort from awk.

Finally, the value of ARGV[0] (see Section 7.5 [Built-in Variables], page 134) varies depending upon your operating system. Some systems put 'awk' there, some put the full pathname of awk (such as /bin/awk), and some put the name of your script ('advice'). Don't rely on the value of ARGV[0] to provide your script name.

1.1.5 Comments in awk Programs

A *comment* is some text that is included in a program for the sake of human readers; it is not really an executable part of the program. Comments can explain what the program does and how it works. Nearly all programming languages have provisions for comments, as programs are typically hard to understand without them.

In the awk language, a comment starts with the sharp sign character ('#') and continues to the end of the line. The '#' does not have to be the first character on the line. The awk language ignores the rest of a line following a sharp sign. For example, we could have put the following into advice:

```
# This program prints a nice friendly message.  It helps
# keep novice users from being afraid of the computer.
BEGIN    { print "Don't Panic!" }
```

You can put comment lines into keyboard-composed throwaway awk programs, but this usually isn't very useful; the purpose of a comment is to help you or another person understand the program when reading it at a later time.

> **CAUTION:** As mentioned in Section 1.1.1 [One-Shot Throwaway awk Programs], page 15, you can enclose small to medium programs in single quotes, in order to keep your shell scripts self-contained. When doing so, *don't* put an apostrophe (i.e., a single quote) into a comment (or anywhere else in your program). The shell interprets the quote as the closing quote for the entire program. As a result, usually the shell prints a message about mismatched quotes, and if awk actually runs, it will probably print strange messages about syntax errors. For example, look at the following:
>
> ```
> $ awk '{ print "hello" } # let's be cute'
> >
> ```
>
> The shell sees that the first two quotes match, and that a new quoted object begins at the end of the command line. It therefore prompts with the secondary prompt, waiting for more input. With Unix awk, closing the quoted string produces this result:
>
> ```
> $ awk '{ print "hello" } # let's be cute'
> > '
> error awk: can't open file be
> error  source line number 1
> ```

Putting a backslash before the single quote in 'let's' wouldn't help, since backslashes are not special inside single quotes. The next subsection describes the shell's quoting rules.

1.1.6 Shell-Quoting Issues

For short to medium length awk programs, it is most convenient to enter the program on the awk command line. This is best done by enclosing the entire program in single quotes. This is true whether you are entering the program interactively at the shell prompt, or writing it as part of a larger shell script:

```
awk 'program text' input-file1 input-file2 ...
```

Once you are working with the shell, it is helpful to have a basic knowledge of shell quoting rules. The following rules apply only to POSIX-compliant, Bourne-style shells (such as Bash, the GNU Bourne-Again Shell). If you use the C shell, you're on your own.

- Quoted items can be concatenated with nonquoted items as well as with other quoted items. The shell turns everything into one argument for the command.
- Preceding any single character with a backslash ('\') quotes that character. The shell removes the backslash and passes the quoted character on to the command.
- Single quotes protect everything between the opening and closing quotes. The shell does no interpretation of the quoted text, passing it on verbatim to the command. It is *impossible* to embed a single quote inside single-quoted text. Refer back to Section 1.1.5 [Comments in awk Programs], page 18, for an example of what happens if you try.
- Double quotes protect most things between the opening and closing quotes. The shell does at least variable and command substitution on the quoted text. Different shells may do additional kinds of processing on double-quoted text.

  Since certain characters within double-quoted text are processed by the shell, they must be *escaped* within the text. Of note are the characters '$', '`', '\', and '"', all of which must be preceded by a backslash within double-quoted text if they are to be passed on literally to the program. (The leading backslash is stripped first.) Thus, the example seen previously in Section 1.1.2 [Running awk Without Input Files], page 16, is applicable:

  ```
  $ awk "BEGIN { print \"Don't Panic!\" }"
  ⊣ Don't Panic!
  ```

  Note that the single quote is not special within double quotes.
- Null strings are removed when they occur as part of a non-null command-line argument, while explicit non-null objects are kept. For example, to specify that the field separator FS should be set to the null string, use:

  ```
  awk -F "" 'program' files # correct
  ```

  Don't use this:

  ```
  awk -F"" 'program' files  # wrong!
  ```

  In the second case, awk will attempt to use the text of the program as the value of FS, and the first file name as the text of the program! This results in syntax errors at best, and confusing behavior at worst.

Mixing single and double quotes is difficult. You have to resort to shell quoting tricks, like this:

```
$ awk 'BEGIN { print "Here is a single quote <'"'"'>" }'
⊣ Here is a single quote <'>
```

This program consists of three concatenated quoted strings. The first and the third are single-quoted, the second is double-quoted.

This can be "simplified" to:

```
$ awk 'BEGIN { print "Here is a single quote <'\''>" }'
⊣ Here is a single quote <'>
```

Judge for yourself which of these two is the more readable.

Another option is to use double quotes, escaping the embedded, `awk`-level double quotes:

```
$ awk "BEGIN { print \"Here is a single quote <'>\" }"
⊣ Here is a single quote <'>
```

This option is also painful, because double quotes, backslashes, and dollar signs are very common in more advanced `awk` programs.

A third option is to use the octal escape sequence equivalents (see Section 3.2 [Escape Sequences], page 44) for the single- and double-quote characters, like so:

```
$ awk 'BEGIN { print "Here is a single quote <\47>" }'
⊣ Here is a single quote <'>
$ awk 'BEGIN { print "Here is a double quote <\42>" }'
⊣ Here is a double quote <">
```

This works nicely, except that you should comment clearly what the escapes mean.

A fourth option is to use command-line variable assignment, like this:

```
$ awk -v sq="'" 'BEGIN { print "Here is a single quote <" sq ">" }'
⊣ Here is a single quote <'>
```

If you really need both single and double quotes in your `awk` program, it is probably best to move it into a separate file, where the shell won't be part of the picture, and you can say what you mean.

1.1.6.1 Quoting in MS-Windows Batch Files

Although this book generally only worries about POSIX systems and the POSIX shell, the following issue arises often enough for many users that it is worth addressing.

The "shells" on Microsoft Windows systems use the double-quote character for quoting, and make it difficult or impossible to include an escaped double-quote character in a command-line script. The following example, courtesy of Jeroen Brink, shows how to print all lines in a file surrounded by double quotes:

```
gawk "{ print \"\042\" $0 \"\042\" }" file
```

1.2 Data Files for the Examples

Many of the examples in this book take their input from two sample data files. The first, `BBS-list`, represents a list of computer bulletin board systems together with information about those systems. The second data file, called `inventory-shipped`, contains information about monthly shipments. In both files, each line is considered to be one *record*.

In the data file `BBS-list`, each record contains the name of a computer bulletin board, its phone number, the board's baud rate(s), and a code for the number of hours it is operational. An 'A' in the last column means the board operates 24 hours a day. A 'B' in the last column means the board only operates on evening and weekend hours. A 'C' means the board operates only on weekends:

```
aardvark     555-5553     1200/300          B
alpo-net     555-3412     2400/1200/300     A
barfly       555-7685     1200/300          A
bites        555-1675     2400/1200/300     A
camelot      555-0542     300               C
core         555-2912     1200/300          C
fooey        555-1234     2400/1200/300     B
foot         555-6699     1200/300          B
macfoo       555-6480     1200/300          A
sdace        555-3430     2400/1200/300     A
sabafoo      555-2127     1200/300          C
```

The data file `inventory-shipped` represents information about shipments during the year. Each record contains the month, the number of green crates shipped, the number of red boxes shipped, the number of orange bags shipped, and the number of blue packages shipped, respectively. There are 16 entries, covering the 12 months of last year and the first four months of the current year.

```
Jan  13  25  15 115
Feb  15  32  24 226
Mar  15  24  34 228
Apr  31  52  63 420
May  16  34  29 208
Jun  31  42  75 492
Jul  24  34  67 436
Aug  15  34  47 316
Sep  13  55  37 277
Oct  29  54  68 525
Nov  20  87  82 577
Dec  17  35  61 401

Jan  21  36  64 620
Feb  26  58  80 652
Mar  24  75  70 495
Apr  21  70  74 514
```

1.3 Some Simple Examples

The following command runs a simple `awk` program that searches the input file `BBS-list` for the character string '`foo`' (a grouping of characters is usually called a *string*; the term *string* is based on similar usage in English, such as "a string of pearls," or "a string of cars in a train"):

```
awk '/foo/ { print $0 }' BBS-list
```

When lines containing '`foo`' are found, they are printed because '`print $0`' means print the current line. (Just '`print`' by itself means the same thing, so we could have written that instead.)

You will notice that slashes ('`/`') surround the string '`foo`' in the `awk` program. The slashes indicate that '`foo`' is the pattern to search for. This type of pattern is called a *regular expression*, which is covered in more detail later (see Chapter 3 [Regular Expressions], page 43). The pattern is allowed to match parts of words. There are single quotes around the `awk` program so that the shell won't interpret any of it as special shell characters.

Here is what this program prints:

```
$ awk '/foo/ { print $0 }' BBS-list
⊣ fooey        555-1234     2400/1200/300     B
⊣ foot         555-6699     1200/300          B
⊣ macfoo       555-6480     1200/300          A
⊣ sabafoo      555-2127     1200/300          C
```

In an `awk` rule, either the pattern or the action can be omitted, but not both. If the pattern is omitted, then the action is performed for *every* input line. If the action is omitted, the default action is to print all lines that match the pattern.

Thus, we could leave out the action (the `print` statement and the curly braces) in the previous example and the result would be the same: `awk` prints all lines matching the pattern '`foo`'. By comparison, omitting the `print` statement but retaining the curly braces makes an empty action that does nothing (i.e., no lines are printed).

Many practical `awk` programs are just a line or two. Following is a collection of useful, short programs to get you started. Some of these programs contain constructs that haven't been covered yet. (The description of the program will give you a good idea of what is going on, but please read the rest of the book to become an `awk` expert!) Most of the examples use a data file named `data`. This is just a placeholder; if you use these programs yourself, substitute your own file names for `data`. For future reference, note that there is often more than one way to do things in `awk`. At some point, you may want to look back at these examples and see if you can come up with different ways to do the same things shown here:

- Print the length of the longest input line:

  ```
  awk '{ if (length($0) > max) max = length($0) }
       END { print max }' data
  ```

- Print every line that is longer than 80 characters:

  ```
  awk 'length($0) > 80' data
  ```

  The sole rule has a relational expression as its pattern and it has no action—so the default action, printing the record, is used.

- Print the length of the longest line in `data`:

  ```
  expand data | awk '{ if (x < length()) x = length() }
                END { print "maximum line length is " x }'
  ```

  The input is processed by the `expand` utility to change TABs into spaces, so the widths compared are actually the right-margin columns.

- Print every line that has at least one field:

  ```
  awk 'NF > 0' data
  ```

This is an easy way to delete blank lines from a file (or rather, to create a new file similar to the old file but from which the blank lines have been removed).

- Print seven random numbers from 0 to 100, inclusive:

```
awk 'BEGIN { for (i = 1; i <= 7; i++)
                 print int(101 * rand()) }'
```

- Print the total number of bytes used by *files*:

```
ls -l files | awk '{ x += $5 }
                  END { print "total bytes: " x }'
```

- Print the total number of kilobytes used by *files*:

```
ls -l files | awk '{ x += $5 }
   END { print "total K-bytes:", x / 1024 }'
```

- Print a sorted list of the login names of all users:

```
awk -F: '{ print $1 }' /etc/passwd | sort
```

- Count the lines in a file:

```
awk 'END { print NR }' data
```

- Print the even-numbered lines in the data file:

```
awk 'NR % 2 == 0' data
```

If you use the expression '`NR % 2 == 1`' instead, the program would print the odd-numbered lines.

1.4 An Example with Two Rules

The `awk` utility reads the input files one line at a time. For each line, `awk` tries the patterns of each of the rules. If several patterns match, then several actions are run in the order in which they appear in the `awk` program. If no patterns match, then no actions are run.

After processing all the rules that match the line (and perhaps there are none), `awk` reads the next line. (However, see Section 7.4.8 [The `next` Statement], page 132, and also see Section 7.4.9 [The `nextfile` Statement], page 133). This continues until the program reaches the end of the file. For example, the following `awk` program contains two rules:

```
/12/  { print $0 }
/21/  { print $0 }
```

The first rule has the string '`12`' as the pattern and '`print $0`' as the action. The second rule has the string '`21`' as the pattern and also has '`print $0`' as the action. Each rule's action is enclosed in its own pair of braces.

This program prints every line that contains the string '`12`' *or* the string '`21`'. If a line contains both strings, it is printed twice, once by each rule.

This is what happens if we run this program on our two sample data files, `BBS-list` and `inventory-shipped`:

```
$ awk '/12/ { print $0 }
>      /21/ { print $0 }' BBS-list inventory-shipped
⊣ aardvark     555-5553     1200/300          B
⊣ alpo-net     555-3412     2400/1200/300     A
⊣ barfly       555-7685     1200/300          A
```

```
-| bites        555-1675     2400/1200/300     A
-| core         555-2912     1200/300          C
-| fooey        555-1234     2400/1200/300     B
-| foot         555-6699     1200/300          B
-| macfoo       555-6480     1200/300          A
-| sdace        555-3430     2400/1200/300     A
-| sabafoo      555-2127     1200/300          C
-| sabafoo      555-2127     1200/300          C
-| Jan  21  36  64 620
-| Apr  21  70  74 514
```

Note how the line beginning with 'sabafoo' in BBS-list was printed twice, once for each rule.

1.5 A More Complex Example

Now that we've mastered some simple tasks, let's look at what typical awk programs do. This example shows how awk can be used to summarize, select, and rearrange the output of another utility. It uses features that haven't been covered yet, so don't worry if you don't understand all the details:

```
LC_ALL=C ls -l | awk '$6 == "Nov" { sum += $5 }
                      END { print sum }'
```

This command prints the total number of bytes in all the files in the current directory that were last modified in November (of any year). The 'ls -l' part of this example is a system command that gives you a listing of the files in a directory, including each file's size and the date the file was last modified. Its output looks like this:

```
-rw-r--r--  1 arnold   user   1933 Nov  7 13:05 Makefile
-rw-r--r--  1 arnold   user  10809 Nov  7 13:03 awk.h
-rw-r--r--  1 arnold   user    983 Apr 13 12:14 awk.tab.h
-rw-r--r--  1 arnold   user  31869 Jun 15 12:20 awkgram.y
-rw-r--r--  1 arnold   user  22414 Nov  7 13:03 awk1.c
-rw-r--r--  1 arnold   user  37455 Nov  7 13:03 awk2.c
-rw-r--r--  1 arnold   user  27511 Dec  9 13:07 awk3.c
-rw-r--r--  1 arnold   user   7989 Nov  7 13:03 awk4.c
```

The first field contains read-write permissions, the second field contains the number of links to the file, and the third field identifies the owner of the file. The fourth field identifies the group of the file. The fifth field contains the size of the file in bytes. The sixth, seventh, and eighth fields contain the month, day, and time, respectively, that the file was last modified. Finally, the ninth field contains the file name.[5]

The '$6 == "Nov"' in our awk program is an expression that tests whether the sixth field of the output from 'ls -l' matches the string 'Nov'. Each time a line has the string 'Nov' for its sixth field, the action 'sum += $5' is performed. This adds the fifth field (the file's size) to the variable sum. As a result, when awk has finished reading all the input lines, sum is the total of the sizes of the files whose lines matched the pattern. (This works because awk variables are automatically initialized to zero.)

---

[5] The 'LC_ALL=C' is needed to produce this traditional-style output from ls.

After the last line of output from `ls` has been processed, the `END` rule executes and prints the value of `sum`. In this example, the value of `sum` is 80600.

These more advanced `awk` techniques are covered in later sections (see Section 7.3 [Actions], page 125). Before you can move on to more advanced `awk` programming, you have to know how `awk` interprets your input and displays your output. By manipulating fields and using `print` statements, you can produce some very useful and impressive-looking reports.

1.6 awk Statements Versus Lines

Most often, each line in an `awk` program is a separate statement or separate rule, like this:

```
awk '/12/  { print $0 }
     /21/  { print $0 }' BBS-list inventory-shipped
```

However, `gawk` ignores newlines after any of the following symbols and keywords:

```
,    {    ?    :    ||    &&    do    else
```

A newline at any other point is considered the end of the statement.[6]

If you would like to split a single statement into two lines at a point where a newline would terminate it, you can *continue* it by ending the first line with a backslash character ('\'). The backslash must be the final character on the line in order to be recognized as a continuation character. A backslash is allowed anywhere in the statement, even in the middle of a string or regular expression. For example:

```
awk '/This regular expression is too long, so continue it\
 on the next line/ { print $1 }'
```

We have generally not used backslash continuation in our sample programs. `gawk` places no limit on the length of a line, so backslash continuation is never strictly necessary; it just makes programs more readable. For this same reason, as well as for clarity, we have kept most statements short in the sample programs presented throughout the book. Backslash continuation is most useful when your `awk` program is in a separate source file instead of entered from the command line. You should also note that many `awk` implementations are more particular about where you may use backslash continuation. For example, they may not allow you to split a string constant using backslash continuation. Thus, for maximum portability of your `awk` programs, it is best not to split your lines in the middle of a regular expression or a string.

> **CAUTION:** *Backslash continuation does not work as described with the C shell.* It works for `awk` programs in files and for one-shot programs, *provided* you are using a POSIX-compliant shell, such as the Unix Bourne shell or Bash. But the C shell behaves differently! There, you must use two backslashes in a row, followed by a newline. Note also that when using the C shell, *every* newline in your `awk` program must be escaped with a backslash. To illustrate:
>
> ```
> % awk 'BEGIN { \
> ?    print \\
> ?            "hello, world" \
> ? }'
> ```

[6] The '?' and ':' referred to here is the three-operand conditional expression described in Section 6.3.4 [Conditional Expressions], page 115. Splitting lines after '?' and ':' is a minor `gawk` extension; if `--posix` is specified (see Section 2.2 [Command-Line Options], page 29), then this extension is disabled.

```
⊣ hello, world
```

Here, the '%' and '?' are the C shell's primary and secondary prompts, analogous to the standard shell's '$' and '>'.

Compare the previous example to how it is done with a POSIX-compliant shell:

```
$ awk 'BEGIN {
>   print \
>       "hello, world"
> }'
⊣ hello, world
```

awk is a line-oriented language. Each rule's action has to begin on the same line as the pattern. To have the pattern and action on separate lines, you *must* use backslash continuation; there is no other option.

Another thing to keep in mind is that backslash continuation and comments do not mix. As soon as awk sees the '#' that starts a comment, it ignores *everything* on the rest of the line. For example:

```
$ gawk 'BEGIN { print "dont panic" # a friendly \
>                                    BEGIN rule
> }'
error gawk: cmd. line:2:                BEGIN rule
error gawk: cmd. line:2:                ^ parse error
```

In this case, it looks like the backslash would continue the comment onto the next line. However, the backslash-newline combination is never even noticed because it is "hidden" inside the comment. Thus, the BEGIN is noted as a syntax error.

When awk statements within one rule are short, you might want to put more than one of them on a line. This is accomplished by separating the statements with a semicolon (';'). This also applies to the rules themselves. Thus, the program shown at the start of this section could also be written this way:

```
/12/ { print $0 } ; /21/ { print $0 }
```

> **NOTE:** The requirement that states that rules on the same line must be separated with a semicolon was not in the original awk language; it was added for consistency with the treatment of statements within an action.

1.7 Other Features of awk

The awk language provides a number of predefined, or *built-in*, variables that your programs can use to get information from awk. There are other variables your program can set as well to control how awk processes your data.

In addition, awk provides a number of built-in functions for doing common computational and string-related operations. gawk provides built-in functions for working with timestamps, performing bit manipulation, for runtime string translation (internationalization), determining the type of a variable, and array sorting.

As we develop our presentation of the awk language, we introduce most of the variables and many of the functions. They are described systematically in Section 7.5 [Built-in Variables], page 134, and Section 9.1 [Built-in Functions], page 159.

1.8 When to Use awk

Now that you've seen some of what awk can do, you might wonder how awk could be useful for you. By using utility programs, advanced patterns, field separators, arithmetic statements, and other selection criteria, you can produce much more complex output. The awk language is very useful for producing reports from large amounts of raw data, such as summarizing information from the output of other utility programs like ls. (See Section 1.5 [A More Complex Example], page 24.)

Programs written with awk are usually much smaller than they would be in other languages. This makes awk programs easy to compose and use. Often, awk programs can be quickly composed at your keyboard, used once, and thrown away. Because awk programs are interpreted, you can avoid the (usually lengthy) compilation part of the typical edit-compile-test-debug cycle of software development.

Complex programs have been written in awk, including a complete retargetable assembler for eight-bit microprocessors (see [Glossary], page 429, for more information), and a microcode assembler for a special-purpose Prolog computer. While the original awk's capabilities were strained by tasks of such complexity, modern versions are more capable. Even Brian Kernighan's version of awk has fewer predefined limits, and those that it has are much larger than they used to be.

If you find yourself writing awk scripts of more than, say, a few hundred lines, you might consider using a different programming language. Emacs Lisp is a good choice if you need sophisticated string or pattern matching capabilities. The shell is also good at string and pattern matching; in addition, it allows powerful use of the system utilities. More conventional languages, such as C, C++, and Java, offer better facilities for system programming and for managing the complexity of large programs. Programs in these languages may require more lines of source code than the equivalent awk programs, but they are easier to maintain and usually run more efficiently.

2 Running `awk` and `gawk`

This chapter covers how to run awk, both POSIX-standard and `gawk`-specific command-line options, and what `awk` and `gawk` do with non-option arguments. It then proceeds to cover how `gawk` searches for source files, reading standard input along with other files, `gawk`'s environment variables, `gawk`'s exit status, using include files, and obsolete and undocumented options and/or features.

Many of the options and features described here are discussed in more detail later in the book; feel free to skip over things in this chapter that don't interest you right now.

2.1 Invoking `awk`

There are two ways to run `awk`—with an explicit program or with one or more program files. Here are templates for both of them; items enclosed in [. . .] in these templates are optional:

```
awk [options] -f progfile [--] file ...
awk [options] [--] 'program' file ...
```

Besides traditional one-letter POSIX-style options, `gawk` also supports GNU long options.

It is possible to invoke `awk` with an empty program:

```
awk '' datafile1 datafile2
```

Doing so makes little sense, though; `awk` exits silently when given an empty program. If `--lint` has been specified on the command line, `gawk` issues a warning that the program is empty.

2.2 Command-Line Options

Options begin with a dash and consist of a single character. GNU-style long options consist of two dashes and a keyword. The keyword can be abbreviated, as long as the abbreviation allows the option to be uniquely identified. If the option takes an argument, then the keyword is either immediately followed by an equals sign ('`=`') and the argument's value, or the keyword and the argument's value are separated by whitespace. If a particular option with a value is given more than once, it is the last value that counts.

Each long option for `gawk` has a corresponding POSIX-style short option. The long and short options are interchangeable in all contexts. The following list describes options mandated by the POSIX standard:

`-F` *`fs`*
`--field-separator` *`fs`*
: Set the `FS` variable to *fs* (see Section 4.5 [Specifying How Fields Are Separated], page 62).

`-f` *`source-file`*
`--file` *`source-file`*
: Read `awk` program source from *source-file* instead of in the first non-option argument. This option may be given multiple times; the `awk` program consists of the concatenation the contents of each specified *source-file*.

`-i source-file`
`--include source-file`

Read `awk` source library from *source-file*. This option is completely equivalent to using the '`@include`' directive inside your program. This option is very similar to the `-f` option, but there are two important differences. First, when `-i` is used, the program source will not be loaded if it has been previously loaded, whereas the `-f` will always load the file. Second, because this option is intended to be used with code libraries, `gawk` does not recognize such files as constituting main program input. Thus, after processing an `-i` argument, `gawk` still expects to find the main source code via the `-f` option or on the command-line.

`-v var=val`
`--assign var=val`

Set the variable *var* to the value *val before* execution of the program begins. Such variable values are available inside the `BEGIN` rule (see Section 2.3 [Other Command-Line Arguments], page 35).

The `-v` option can only set one variable, but it can be used more than once, setting another variable each time, like this: '`awk -v foo=1 -v bar=2 ...`'.

> **CAUTION:** Using `-v` to set the values of the built-in variables may lead to surprising results. `awk` will reset the values of those variables as it needs to, possibly ignoring any predefined value you may have given.

`-W gawk-opt`

Provide an implementation-specific option. This is the POSIX convention for providing implementation-specific options. These options also have corresponding GNU-style long options. Note that the long options may be abbreviated, as long as the abbreviations remain unique. The full list of `gawk`-specific options is provided next.

`--`

Signal the end of the command-line options. The following arguments are not treated as options even if they begin with '`-`'. This interpretation of `--` follows the POSIX argument parsing conventions.

This is useful if you have file names that start with '`-`', or in shell scripts, if you have file names that will be specified by the user that could start with '`-`'. It is also useful for passing options on to the `awk` program; see Section 10.4 [Processing Command-Line Options], page 216.

The following list describes `gawk`-specific options:

`-b`
`--characters-as-bytes`

Cause `gawk` to treat all input data as single-byte characters. In addition, all output written with `print` or `printf` are treated as single-byte characters.

Normally, `gawk` follows the POSIX standard and attempts to process its input data according to the current locale. This can often involve converting multibyte characters into wide characters (internally), and can lead to problems or confusion if the input data does not contain valid multibyte characters. This option is an easy way to tell `gawk`: "hands off my data!".

`-c`
`--traditional`
Specify *compatibility mode*, in which the GNU extensions to the awk language are disabled, so that gawk behaves just like Brian Kernighan's version awk. See Section A.5 [Extensions in gawk Not in POSIX awk], page 391, which summarizes the extensions. Also see Section C.1 [Downward Compatibility and Debugging], page 415.

`-C`
`--copyright`
Print the short version of the General Public License and then exit.

`-d[file]`
`--dump-variables[=file]`
Print a sorted list of global variables, their types, and final values to *file*. If no *file* is provided, print this list to the file named awkvars.out in the current directory. No space is allowed between the -d and *file*, if *file* is supplied.

Having a list of all global variables is a good way to look for typographical errors in your programs. You would also use this option if you have a large program with a lot of functions, and you want to be sure that your functions don't inadvertently use global variables that you meant to be local. (This is a particularly easy mistake to make with simple variable names like i, j, etc.)

`-D[file]`
`--debug=[file]`
Enable debugging of awk programs (see Section 14.1 [Introduction to gawk Debugger], page 301). By default, the debugger reads commands interactively from the terminal. The optional *file* argument allows you to specify a file with a list of commands for the debugger to execute non-interactively. No space is allowed between the -D and *file*, if *file* is supplied.

`-e program-text`
`--source program-text`
Provide program source code in the *program-text*. This option allows you to mix source code in files with source code that you enter on the command line. This is particularly useful when you have library functions that you want to use from your command-line programs (see Section 2.5.1 [The AWKPATH Environment Variable], page 36).

`-E file`
`--exec file`
Similar to -f, read awk program text from *file*. There are two differences from -f:

- This option terminates option processing; anything else on the command line is passed on directly to the awk program.
- Command-line variable assignments of the form '*var=value*' are disallowed.

This option is particularly necessary for World Wide Web CGI applications that pass arguments through the URL; using this option prevents a malicious (or other) user from passing in options, assignments, or awk source code (via --source) to the CGI application. This option should be used with '#!' scripts (see Section 1.1.4 [Executable awk Programs], page 17), like so:

```
#! /usr/local/bin/gawk -E

awk program here ...
```

-g
--gen-pot
: Analyze the source program and generate a GNU gettext Portable Object Template file on standard output for all string constants that have been marked for translation. See Chapter 13 [Internationalization with gawk], page 291, for information about this option.

-h
--help
: Print a "usage" message summarizing the short and long style options that gawk accepts and then exit.

-l *lib*
--load *lib*
: Load a shared library *lib*. This searches for the library using the AWKLIBPATH environment variable. The correct library suffix for your platform will be supplied by default, so it need not be specified in the library name. The library initialization routine should be named dl_load(). An alternative is to use the '@load' keyword inside the program to load a shared library.

-L [value]
--lint[=value]
: Warn about constructs that are dubious or nonportable to other awk implementations. Some warnings are issued when gawk first reads your program. Others are issued at runtime, as your program executes. With an optional argument of 'fatal', lint warnings become fatal errors. This may be drastic, but its use will certainly encourage the development of cleaner awk programs. With an optional argument of 'invalid', only warnings about things that are actually invalid are issued. (This is not fully implemented yet.)

Some warnings are only printed once, even if the dubious constructs they warn about occur multiple times in your awk program. Thus, when eliminating problems pointed out by --lint, you should take care to search for all occurrences of each inappropriate construct. As awk programs are usually short, doing so is not burdensome.

-M
--bignum
: Force arbitrary precision arithmetic on numbers. This option has no effect if gawk is not compiled to use the GNU MPFR and MP libraries (see Chapter 15 [Arithmetic and Arbitrary Precision Arithmetic with gawk], page 317).

-n
--non-decimal-data
: Enable automatic interpretation of octal and hexadecimal values in input data (see Section 12.1 [Allowing Nondecimal Input Data], page 277).

CAUTION: This option can severely break old programs. Use with care.

`-N`
`--use-lc-numeric`
Force the use of the locale's decimal point character when parsing numeric input data (see Section 6.6 [Where You Are Makes A Difference], page 118).

`-o`[*file*]
`--pretty-print`[=*file*]
Enable pretty-printing of `awk` programs. By default, output program is created in a file named `awkprof.out`. The optional *file* argument allows you to specify a different file name for the output. No space is allowed between the `-o` and *file*, if *file* is supplied.

`-O`
`--optimize`
Enable some optimizations on the internal representation of the program. At the moment this includes just simple constant folding. The `gawk` maintainer hopes to add more optimizations over time.

`-p`[*file*]
`--profile`[=*file*]
Enable profiling of `awk` programs (see Section 12.5 [Profiling Your awk Programs], page 287). By default, profiles are created in a file named `awkprof.out`. The optional *file* argument allows you to specify a different file name for the profile file. No space is allowed between the `-p` and *file*, if *file* is supplied.

The profile contains execution counts for each statement in the program in the left margin, and function call counts for each function.

`-P`
`--posix`
Operate in strict POSIX mode. This disables all `gawk` extensions (just like `--traditional`) and disables all extensions not allowed by POSIX. See Section A.6 [Common Extensions Summary], page 393, for a summary of the extensions in `gawk` that are disabled by this option. Also, the following additional restrictions apply:

- Newlines do not act as whitespace to separate fields when `FS` is equal to a single space (see Section 4.2 [Examining Fields], page 58).
- Newlines are not allowed after '`?`' or '`:`' (see Section 6.3.4 [Conditional Expressions], page 115).
- Specifying '`-Ft`' on the command-line does not set the value of `FS` to be a single TAB character (see Section 4.5 [Specifying How Fields Are Separated], page 62).
- The locale's decimal point character is used for parsing input data (see Section 6.6 [Where You Are Makes A Difference], page 118).

If you supply both `--traditional` and `--posix` on the command line, `--posix` takes precedence. `gawk` also issues a warning if both options are supplied.

`-r`
`--re-interval`

Allow interval expressions (see Section 3.3 [Regular Expression Operators], page 46) in regexps. This is now `gawk`'s default behavior. Nevertheless, this option remains both for backward compatibility, and for use in combination with the `--traditional` option.

`-S`
`--sandbox`

Disable the `system()` function, input redirections with `getline`, output redirections with `print` and `printf`, and dynamic extensions. This is particularly useful when you want to run `awk` scripts from questionable sources and need to make sure the scripts can't access your system (other than the specified input data file).

`-t`
`--lint-old`

Warn about constructs that are not available in the original version of `awk` from Version 7 Unix (see Section A.1 [Major Changes Between V7 and SVR3.1], page 389).

`-V`
`--version`

Print version information for this particular copy of `gawk`. This allows you to determine if your copy of `gawk` is up to date with respect to whatever the Free Software Foundation is currently distributing. It is also useful for bug reports (see Section B.4 [Reporting Problems and Bugs], page 410).

As long as program text has been supplied, any other options are flagged as invalid with a warning message but are otherwise ignored.

In compatibility mode, as a special case, if the value of *fs* supplied to the `-F` option is '`t`', then `FS` is set to the TAB character (`"\t"`). This is true only for `--traditional` and not for `--posix` (see Section 4.5 [Specifying How Fields Are Separated], page 62).

The `-f` option may be used more than once on the command line. If it is, `awk` reads its program source from all of the named files, as if they had been concatenated together into one big file. This is useful for creating libraries of `awk` functions. These functions can be written once and then retrieved from a standard place, instead of having to be included into each individual program. (As mentioned in Section 9.2.1 [Function Definition Syntax], page 184, function names must be unique.)

With standard `awk`, library functions can still be used, even if the program is entered at the terminal, by specifying '`-f /dev/tty`'. After typing your program, type *`Ctrl-d`* (the end-of-file character) to terminate it. (You may also use '`-f -`' to read program source from the standard input but then you will not be able to also use the standard input as a source of data.)

Because it is clumsy using the standard `awk` mechanisms to mix source file and command-line `awk` programs, `gawk` provides the `--source` option. This does not require you to preempt the standard input for your source code; it allows you to easily mix command-line and library source code (see Section 2.5.1 [The `AWKPATH` Environment Variable], page 36). The `--source` option may also be used multiple times on the command line.

If no `-f` or `--source` option is specified, then `gawk` uses the first non-option command-line argument as the text of the program source code.

If the environment variable `POSIXLY_CORRECT` exists, then `gawk` behaves in strict POSIX mode, exactly as if you had supplied the `--posix` command-line option. Many GNU programs look for this environment variable to suppress extensions that conflict with POSIX, but `gawk` behaves differently: it suppresses all extensions, even those that do not conflict with POSIX, and behaves in strict POSIX mode. If `--lint` is supplied on the command line and `gawk` turns on POSIX mode because of `POSIXLY_CORRECT`, then it issues a warning message indicating that POSIX mode is in effect. You would typically set this variable in your shell's startup file. For a Bourne-compatible shell (such as Bash), you would add these lines to the `.profile` file in your home directory:

```
POSIXLY_CORRECT=true
export POSIXLY_CORRECT
```

For a C shell-compatible shell,[1] you would add this line to the `.login` file in your home directory:

```
setenv POSIXLY_CORRECT true
```

Having `POSIXLY_CORRECT` set is not recommended for daily use, but it is good for testing the portability of your programs to other environments.

2.3 Other Command-Line Arguments

Any additional arguments on the command line are normally treated as input files to be processed in the order specified. However, an argument that has the form `var=value`, assigns the value *value* to the variable *var*—it does not specify a file at all. (See Section 6.1.3.2 [Assigning Variables on the Command Line], page 100.)

All these arguments are made available to your `awk` program in the `ARGV` array (see Section 7.5 [Built-in Variables], page 134). Command-line options and the program text (if present) are omitted from `ARGV`. All other arguments, including variable assignments, are included. As each element of `ARGV` is processed, `gawk` sets the variable `ARGIND` to the index in `ARGV` of the current element.

The distinction between file name arguments and variable-assignment arguments is made when `awk` is about to open the next input file. At that point in execution, it checks the file name to see whether it is really a variable assignment; if so, `awk` sets the variable instead of reading a file.

Therefore, the variables actually receive the given values after all previously specified files have been read. In particular, the values of variables assigned in this fashion are *not* available inside a `BEGIN` rule (see Section 7.1.4 [The BEGIN and END Special Patterns], page 122), because such rules are run before `awk` begins scanning the argument list.

The variable values given on the command line are processed for escape sequences (see Section 3.2 [Escape Sequences], page 44).

In some earlier implementations of `awk`, when a variable assignment occurred before any file names, the assignment would happen *before* the `BEGIN` rule was executed. `awk`'s behavior was thus inconsistent; some command-line assignments were available inside the

[1] Not recommended.

BEGIN rule, while others were not. Unfortunately, some applications came to depend upon this "feature." When awk was changed to be more consistent, the -v option was added to accommodate applications that depended upon the old behavior.

The variable assignment feature is most useful for assigning to variables such as RS, OFS, and ORS, which control input and output formats before scanning the data files. It is also useful for controlling state if multiple passes are needed over a data file. For example:

```
awk 'pass == 1  { pass 1 stuff }
     pass == 2  { pass 2 stuff }' pass=1 mydata pass=2 mydata
```

Given the variable assignment feature, the -F option for setting the value of FS is not strictly necessary. It remains for historical compatibility.

2.4 Naming Standard Input

Often, you may wish to read standard input together with other files. For example, you may wish to read one file, read standard input coming from a pipe, and then read another file.

The way to name the standard input, with all versions of awk, is to use a single, standalone minus sign or dash, '-'. For example:

```
some_command | awk -f myprog.awk file1 - file2
```

Here, awk first reads file1, then it reads the output of *some_command*, and finally it reads file2.

You may also use "-" to name standard input when reading files with getline (see Section 4.9.3 [Using getline from a File], page 75).

In addition, gawk allows you to specify the special file name /dev/stdin, both on the command line and with getline. Some other versions of awk also support this, but it is not standard. (Some operating systems provide a /dev/stdin file in the file system, however, gawk always processes this file name itself.)

2.5 The Environment Variables gawk Uses

A number of environment variables influence how gawk behaves.

2.5.1 The AWKPATH Environment Variable

In most awk implementations, you must supply a precise path name for each program file, unless the file is in the current directory. But in gawk, if the file name supplied to the -f or -i options does not contain a '/', then gawk searches a list of directories (called the *search path*), one by one, looking for a file with the specified name.

The search path is a string consisting of directory names separated by colons. gawk gets its search path from the AWKPATH environment variable. If that variable does not exist, gawk uses a default path, '.:/usr/local/share/awk'.[2]

The search path feature is particularly useful for building libraries of useful awk functions. The library files can be placed in a standard directory in the default path and then specified

[2] Your version of gawk may use a different directory; it will depend upon how gawk was built and installed. The actual directory is the value of '$(datadir)' generated when gawk was configured. You probably don't need to worry about this, though.

on the command line with a short file name. Otherwise, the full file name would have to be typed for each file.

By using the -i option, or the --source and -f options, your command-line awk programs can use facilities in awk library files (see Chapter 10 [A Library of awk Functions], page 201). Path searching is not done if gawk is in compatibility mode. This is true for both --traditional and --posix. See Section 2.2 [Command-Line Options], page 29.

If the source code is not found after the initial search, the path is searched again after adding the default '.awk' suffix to the filename.

> **NOTE:** To include the current directory in the path, either place . explicitly in the path or write a null entry in the path. (A null entry is indicated by starting or ending the path with a colon or by placing two colons next to each other ('::').) This path search mechanism is similar to the shell's.
>
> However, gawk always looks in the current directory *before* searching AWKPATH, so there is no real reason to include the current directory in the search path.

If AWKPATH is not defined in the environment, gawk places its default search path into ENVIRON["AWKPATH"]. This makes it easy to determine the actual search path that gawk will use from within an awk program.

While you can change ENVIRON["AWKPATH"] within your awk program, this has no effect on the running program's behavior. This makes sense: the AWKPATH environment variable is used to find the program source files. Once your program is running, all the files have been found, and gawk no longer needs to use AWKPATH.

2.5.2 The AWKLIBPATH Environment Variable

The AWKLIBPATH environment variable is similar to the AWKPATH variable, but it is used to search for shared libraries specified with the -l option rather than for source files. If the library is not found, the path is searched again after adding the appropriate shared library suffix for the platform. For example, on GNU/Linux systems, the suffix '.so' is used. The search path specified is also used for libraries loaded via the '@load' keyword (see Section 2.8 [Loading Shared Libraries Into Your Program], page 40).

2.5.3 Other Environment Variables

A number of other environment variables affect gawk's behavior, but they are more specialized. Those in the following list are meant to be used by regular users.

POSIXLY_CORRECT
: Causes gawk to switch POSIX compatibility mode, disabling all traditional and GNU extensions. See Section 2.2 [Command-Line Options], page 29.

GAWK_SOCK_RETRIES
: Controls the number of time gawk will attempt to retry a two-way TCP/IP (socket) connection before giving up. See Section 12.4 [Using gawk for Network Programming], page 285.

GAWK_MSEC_SLEEP
: Specifies the interval between connection retries, in milliseconds. On systems that do not support the usleep() system call, the value is rounded up to an integral number of seconds.

`GAWK_READ_TIMEOUT`
: Specifies the time, in milliseconds, for `gawk` to wait for input before returning with an error. See Section 4.10 [Reading Input With A Timeout], page 79.

The environment variables in the following list are meant for use by the `gawk` developers for testing and tuning. They are subject to change. The variables are:

`AWK_HASH`
: If this variable exists with a value of '`gst`', `gawk` will switch to using the hash function from GNU Smalltalk for managing arrays. This function may be marginally faster than the standard function.

`AWKREADFUNC`
: If this variable exists, `gawk` switches to reading source files one line at a time, instead of reading in blocks. This exists for debugging problems on filesystems on non-POSIX operating systems where I/O is performed in records, not in blocks.

`GAWK_MSG_SRC`
: If this variable exists, `gawk` includes the source file name and line number from which warning and/or fatal messages are generated. Its purpose is to help isolate the source of a message, since there can be multiple places which produce the same warning or error message.

`GAWK_NO_DFA`
: If this variable exists, `gawk` does not use the DFA regexp matcher for "does it match" kinds of tests. This can cause `gawk` to be slower. Its purpose is to help isolate differences between the two regexp matchers that `gawk` uses internally. (There aren't supposed to be differences, but occasionally theory and practice don't coordinate with each other.)

`GAWK_STACKSIZE`
: This specifies the amount by which `gawk` should grow its internal evaluation stack, when needed.

`INT_CHAIN_MAX`
: The average number of items `gawk` will maintain on a hash chain for managing arrays indexed by integers.

`STR_CHAIN_MAX`
: The average number of items `gawk` will maintain on a hash chain for managing arrays indexed by strings.

`TIDYMEM`
: If this variable exists, `gawk` uses the `mtrace()` library calls from GNU LIBC to help track down possible memory leaks.

2.6 `gawk`'s Exit Status

If the `exit` statement is used with a value (see Section 7.4.10 [The `exit` Statement], page 134), then `gawk` exits with the numeric value given to it.

Otherwise, if there were no problems during execution, `gawk` exits with the value of the C constant `EXIT_SUCCESS`. This is usually zero.

If an error occurs, gawk exits with the value of the C constant EXIT_FAILURE. This is usually one.

If gawk exits because of a fatal error, the exit status is 2. On non-POSIX systems, this value may be mapped to EXIT_FAILURE.

2.7 Including Other Files Into Your Program

This section describes a feature that is specific to gawk.

The '@include' keyword can be used to read external awk source files. This gives you the ability to split large awk source files into smaller, more manageable pieces, and also lets you reuse common awk code from various awk scripts. In other words, you can group together awk functions, used to carry out specific tasks, into external files. These files can be used just like function libraries, using the '@include' keyword in conjunction with the AWKPATH environment variable. Note that source files may also be included using the -i option.

Let's see an example. We'll start with two (trivial) awk scripts, namely test1 and test2. Here is the test1 script:

```
BEGIN {
    print "This is script test1."
}
```

and here is test2:

```
@include "test1"
BEGIN {
    print "This is script test2."
}
```

Running gawk with test2 produces the following result:

```
$ gawk -f test2
⊣ This is file test1.
⊣ This is file test2.
```

gawk runs the test2 script which includes test1 using the '@include' keyword. So, to include external awk source files you just use '@include' followed by the name of the file to be included, enclosed in double quotes.

> **NOTE:** Keep in mind that this is a language construct and the file name cannot be a string variable, but rather just a literal string in double quotes.

The files to be included may be nested; e.g., given a third script, namely test3:

```
@include "test2"
BEGIN {
    print "This is script test3."
}
```

Running gawk with the test3 script produces the following results:

```
$ gawk -f test3
⊣ This is file test1.
⊣ This is file test2.
⊣ This is file test3.
```

The file name can, of course, be a pathname. For example:

```
@include "../io_funcs"
```

or:

```
@include "/usr/awklib/network"
```

are valid. The AWKPATH environment variable can be of great value when using '@include'. The same rules for the use of the AWKPATH variable in command-line file searches (see Section 2.5.1 [The AWKPATH Environment Variable], page 36) apply to '@include' also.

This is very helpful in constructing gawk function libraries. If you have a large script with useful, general purpose awk functions, you can break it down into library files and put those files in a special directory. You can then include those "libraries," using either the full pathnames of the files, or by setting the AWKPATH environment variable accordingly and then using '@include' with just the file part of the full pathname. Of course you can have more than one directory to keep library files; the more complex the working environment is, the more directories you may need to organize the files to be included.

Given the ability to specify multiple -f options, the '@include' mechanism is not strictly necessary. However, the '@include' keyword can help you in constructing self-contained gawk programs, thus reducing the need for writing complex and tedious command lines. In particular, '@include' is very useful for writing CGI scripts to be run from web pages.

As mentioned in Section 2.5.1 [The AWKPATH Environment Variable], page 36, the current directory is always searched first for source files, before searching in AWKPATH, and this also applies to files named with '@include'.

2.8 Loading Shared Libraries Into Your Program

This section describes a feature that is specific to gawk.

The '@load' keyword can be used to read external awk shared libraries. This allows you to link in compiled code that may offer superior performance and/or give you access to extended capabilities not supported by the awk language. The AWKLIBPATH variable is used to search for the shared library. Using '@load' is completely equivalent to using the -l command-line option.

If the shared library is not initially found in AWKLIBPATH, another search is conducted after appending the platform's default shared library suffix to the filename. For example, on GNU/Linux systems, the suffix '.so' is used.

```
$ gawk '@load "ordchr"; BEGIN {print chr(65)}'
⊣ A
```

This is equivalent to the following example:

```
$ gawk -lordchr 'BEGIN {print chr(65)}'
⊣ A
```

For command-line usage, the -l option is more convenient, but '@load' is useful for embedding inside an awk source file that requires access to a shared library.

Chapter 16 [Writing Extensions for gawk], page 333, describes how to write extensions (in C or C++) that can be loaded with either '@load' or the -l option.

2.9 Obsolete Options and/or Features

This section describes features and/or command-line options from previous releases of `gawk` that are either not available in the current version or that are still supported but deprecated (meaning that they will *not* be in the next release).

The process-related special files `/dev/pid`, `/dev/ppid`, `/dev/pgrpid`, and `/dev/user` were deprecated in `gawk` 3.1, but still worked. As of version 4.0, they are no longer interpreted specially by `gawk`. (Use `PROCINFO` instead; see Section 7.5.2 [Built-in Variables That Convey Information], page 137.)

2.10 Undocumented Options and Features

> *Use the Source, Luke!*
> Obi-Wan

This section intentionally left blank.

3 Regular Expressions

A *regular expression*, or *regexp*, is a way of describing a set of strings. Because regular expressions are such a fundamental part of `awk` programming, their format and use deserve a separate chapter.

A regular expression enclosed in slashes (‘/’) is an `awk` pattern that matches every input record whose text belongs to that set. The simplest regular expression is a sequence of letters, numbers, or both. Such a regexp matches any string that contains that sequence. Thus, the regexp ‘foo’ matches any string containing ‘foo’. Therefore, the pattern `/foo/` matches any input record containing the three characters ‘foo’ *anywhere* in the record. Other kinds of regexps let you specify more complicated classes of strings.

Initially, the examples in this chapter are simple. As we explain more about how regular expressions work, we present more complicated instances.

3.1 How to Use Regular Expressions

A regular expression can be used as a pattern by enclosing it in slashes. Then the regular expression is tested against the entire text of each record. (Normally, it only needs to match some part of the text in order to succeed.) For example, the following prints the second field of each record that contains the string ‘foo’ anywhere in it:

```
$ awk '/foo/ { print $2 }' BBS-list
⊣ 555-1234
⊣ 555-6699
⊣ 555-6480
⊣ 555-2127
```

Regular expressions can also be used in matching expressions. These expressions allow you to specify the string to match against; it need not be the entire current input record. The two operators ‘~’ and ‘!~’ perform regular expression comparisons. Expressions using these operators can be used as patterns, or in `if`, `while`, `for`, and `do` statements. (See Section 7.4 [Control Statements in Actions], page 126.) For example:

```
exp ~ /regexp/
```

is true if the expression *exp* (taken as a string) matches *regexp*. The following example matches, or selects, all input records with the uppercase letter ‘J’ somewhere in the first field:

```
$ awk '$1 ~ /J/' inventory-shipped
⊣ Jan  13  25  15 115
⊣ Jun  31  42  75 492
⊣ Jul  24  34  67 436
⊣ Jan  21  36  64 620
```

So does this:

```
awk '{ if ($1 ~ /J/) print }' inventory-shipped
```

This next example is true if the expression *exp* (taken as a character string) does *not* match *regexp*:

```
exp !~ /regexp/
```

The following example matches, or selects, all input records whose first field *does not* contain the uppercase letter 'J':

```
$ awk '$1 !~ /J/' inventory-shipped
⊣ Feb  15  32  24 226
⊣ Mar  15  24  34 228
⊣ Apr  31  52  63 420
⊣ May  16  34  29 208
...
```

When a regexp is enclosed in slashes, such as `/foo/`, we call it a *regexp constant*, much like `5.27` is a numeric constant and `"foo"` is a string constant.

3.2 Escape Sequences

Some characters cannot be included literally in string constants (`"foo"`) or regexp constants (`/foo/`). Instead, they should be represented with *escape sequences*, which are character sequences beginning with a backslash ('`\`'). One use of an escape sequence is to include a double-quote character in a string constant. Because a plain double quote ends the string, you must use '`\"`' to represent an actual double-quote character as a part of the string. For example:

```
$ awk 'BEGIN { print "He said \"hi!\" to her." }'
⊣ He said "hi!" to her.
```

The backslash character itself is another character that cannot be included normally; you must write '`\\`' to put one backslash in the string or regexp. Thus, the string whose contents are the two characters '`"`' and '`\`' must be written `"\"\\"`.

Other escape sequences represent unprintable characters such as TAB or newline. While there is nothing to stop you from entering most unprintable characters directly in a string constant or regexp constant, they may look ugly.

The following table lists all the escape sequences used in `awk` and what they represent. Unless noted otherwise, all these escape sequences apply to both string constants and regexp constants:

`\\`
: A literal backslash, '`\`'.

`\a`
: The "alert" character, *Ctrl-g*, ASCII code 7 (BEL). (This usually makes some sort of audible noise.)

`\b`
: Backspace, *Ctrl-h*, ASCII code 8 (BS).

`\f`
: Formfeed, *Ctrl-l*, ASCII code 12 (FF).

`\n`
: Newline, *Ctrl-j*, ASCII code 10 (LF).

`\r`
: Carriage return, *Ctrl-m*, ASCII code 13 (CR).

`\t`
: Horizontal TAB, *Ctrl-i*, ASCII code 9 (HT).

`\v`
: Vertical tab, *Ctrl-k*, ASCII code 11 (VT).

`\nnn`
: The octal value *nnn*, where *nnn* stands for 1 to 3 digits between '`0`' and '`7`'. For example, the code for the ASCII ESC (escape) character is '`\033`'.

`\xhh...` The hexadecimal value *hh*, where *hh* stands for a sequence of hexadecimal digits (‘`0`’–‘`9`’, and either ‘`A`’–‘`F`’ or ‘`a`’–‘`f`’). Like the same construct in ISO C, the escape sequence continues until the first nonhexadecimal digit is seen. (c.e.) However, using more than two hexadecimal digits produces undefined results. (The ‘`\x`’ escape sequence is not allowed in POSIX `awk`.)

`\/` A literal slash (necessary for regexp constants only). This sequence is used when you want to write a regexp constant that contains a slash. Because the regexp is delimited by slashes, you need to escape the slash that is part of the pattern, in order to tell `awk` to keep processing the rest of the regexp.

`\"` A literal double quote (necessary for string constants only). This sequence is used when you want to write a string constant that contains a double quote. Because the string is delimited by double quotes, you need to escape the quote that is part of the string, in order to tell `awk` to keep processing the rest of the string.

In `gawk`, a number of additional two-character sequences that begin with a backslash have special meaning in regexps. See Section 3.5 [`gawk`-Specific Regexp Operators], page 50.

In a regexp, a backslash before any character that is not in the previous list and not listed in Section 3.5 [`gawk`-Specific Regexp Operators], page 50, means that the next character should be taken literally, even if it would normally be a regexp operator. For example, `/a\+b/` matches the three characters ‘`a+b`’.

For complete portability, do not use a backslash before any character not shown in the previous list.

To summarize:

- The escape sequences in the table above are always processed first, for both string constants and regexp constants. This happens very early, as soon as `awk` reads your program.
- `gawk` processes both regexp constants and dynamic regexps (see Section 3.8 [Using Dynamic Regexps], page 53), for the special operators listed in Section 3.5 [`gawk`-Specific Regexp Operators], page 50.
- A backslash before any other character means to treat that character literally.

Backslash Before Regular Characters

If you place a backslash in a string constant before something that is not one of the characters previously listed, POSIX `awk` purposely leaves what happens as undefined. There are two choices:

Strip the backslash out
: This is what Brian Kernighan's `awk` and `gawk` both do. For example, `"a\qc"` is the same as `"aqc"`. (Because this is such an easy bug both to introduce and to miss, `gawk` warns you about it.) Consider '`FS = "[ \t]+\|[ \t]+"`' to use vertical bars surrounded by whitespace as the field separator. There should be two backslashes in the string: '`FS = "[ \t]+\\|[ \t]+"`'.)

Leave the backslash alone
: Some other `awk` implementations do this. In such implementations, typing `"a\qc"` is the same as typing `"a\\qc"`.

Escape Sequences for Metacharacters

Suppose you use an octal or hexadecimal escape to represent a regexp metacharacter. (See Section 3.3 [Regular Expression Operators], page 46.) Does `awk` treat the character as a literal character or as a regexp operator?

Historically, such characters were taken literally. However, the POSIX standard indicates that they should be treated as real metacharacters, which is what `gawk` does. In compatibility mode (see Section 2.2 [Command-Line Options], page 29), `gawk` treats the characters represented by octal and hexadecimal escape sequences literally when used in regexp constants. Thus, `/a\52b/` is equivalent to `/a\*b/`.

3.3 Regular Expression Operators

You can combine regular expressions with special characters, called *regular expression operators* or *metacharacters*, to increase the power and versatility of regular expressions.

The escape sequences described earlier in Section 3.2 [Escape Sequences], page 44, are valid inside a regexp. They are introduced by a '\' and are recognized and converted into corresponding real characters as the very first step in processing regexps.

Here is a list of metacharacters. All characters that are not escape sequences and that are not listed in the table stand for themselves:

`\`
: This is used to suppress the special meaning of a character when matching. For example, '`\$`' matches the character '`$`'.

`^`
: This matches the beginning of a string. For example, '`^@chapter`' matches '`@chapter`' at the beginning of a string and can be used to identify chapter beginnings in Texinfo source files. The '`^`' is known as an *anchor*, because it anchors the pattern to match only at the beginning of the string.

: It is important to realize that '`^`' does not match the beginning of a line embedded in a string. The condition is not true in the following example:

```
if ("line1\nLINE 2" ~ /^L/) ...
```

`$` This is similar to '`^`', but it matches only at the end of a string. For example, '`p$`' matches a record that ends with a '`p`'. The '`$`' is an anchor and does not match the end of a line embedded in a string. The condition in the following example is not true:

```
if ("line1\nLINE 2" ~ /1$/) ...
```

. (period) This matches any single character, *including* the newline character. For example, '`.P`' matches any single character followed by a '`P`' in a string. Using concatenation, we can make a regular expression such as '`U.A`', which matches any three-character sequence that begins with '`U`' and ends with '`A`'.

In strict POSIX mode (see Section 2.2 [Command-Line Options], page 29), '`.`' does not match the NUL character, which is a character with all bits equal to zero. Otherwise, NUL is just another character. Other versions of `awk` may not be able to match the NUL character.

`[...]` This is called a *bracket expression*.[1] It matches any *one* of the characters that are enclosed in the square brackets. For example, '`[MVX]`' matches any one of the characters '`M`', '`V`', or '`X`' in a string. A full discussion of what can be inside the square brackets of a bracket expression is given in Section 3.4 [Using Bracket Expressions], page 49.

`[^ ...]` This is a *complemented bracket expression*. The first character after the '`[`' *must* be a '`^`'. It matches any characters *except* those in the square brackets. For example, '`[^awk]`' matches any character that is not an '`a`', '`w`', or '`k`'.

`|` This is the *alternation operator* and it is used to specify alternatives. The '`|`' has the lowest precedence of all the regular expression operators. For example, '`^P|[[:digit:]]`' matches any string that matches either '`^P`' or '`[[:digit:]]`'. This means it matches any string that starts with '`P`' or contains a digit.

The alternation applies to the largest possible regexps on either side.

`(...)` Parentheses are used for grouping in regular expressions, as in arithmetic. They can be used to concatenate regular expressions containing the alternation operator, '`|`'. For example, '`@(samp|code)\{[^}]+\}`' matches both '`@code{foo}`' and '`@samp{bar}`'. (These are Texinfo formatting control sequences. The '`+`' is explained further on in this list.)

`*` This symbol means that the preceding regular expression should be repeated as many times as necessary to find a match. For example, '`ph*`' applies the '`*`' symbol to the preceding '`h`' and looks for matches of one '`p`' followed by any number of '`h`'s. This also matches just '`p`' if no '`h`'s are present.

The '`*`' repeats the *smallest* possible preceding expression. (Use parentheses if you want to repeat a larger expression.) It finds as many repetitions as possible. For example, '`awk '/\(c[ad][ad]*r x\)/ { print }' sample`' prints every record in `sample` containing a string of the form '`(car x)`', '`(cdr x)`', '`(cadr x)`', and so on. Notice the escaping of the parentheses by preceding them with backslashes.

[1] In other literature, you may see a bracket expression referred to as either a *character set*, a *character class*, or a *character list*.

`+` This symbol is similar to '`*`', except that the preceding expression must be matched at least once. This means that '`wh+y`' would match '`why`' and '`whhy`', but not '`wy`', whereas '`wh*y`' would match all three of these strings. The following is a simpler way of writing the last '`*`' example:

```
awk '/\(c[ad]+r x\)/ { print }' sample
```

`?` This symbol is similar to '`*`', except that the preceding expression can be matched either once or not at all. For example, '`fe?d`' matches '`fed`' and '`fd`', but nothing else.

`{`*n*`}`
`{`*n*`,}`
`{`*n*`,`*m*`}` One or two numbers inside braces denote an *interval expression*. If there is one number in the braces, the preceding regexp is repeated *n* times. If there are two numbers separated by a comma, the preceding regexp is repeated *n* to *m* times. If there is one number followed by a comma, then the preceding regexp is repeated at least *n* times:

`wh{3}y` Matches '`whhhy`', but not '`why`' or '`whhhhy`'.

`wh{3,5}y` Matches '`whhhy`', '`whhhhy`', or '`whhhhhy`', only.

`wh{2,}y` Matches '`whhy`' or '`whhhy`', and so on.

Interval expressions were not traditionally available in `awk`. They were added as part of the POSIX standard to make `awk` and `egrep` consistent with each other.

Initially, because old programs may use '`{`' and '`}`' in regexp constants, `gawk` did *not* match interval expressions in regexps.

However, beginning with version 4.0, `gawk` does match interval expressions by default. This is because compatibility with POSIX has become more important to most `gawk` users than compatibility with old programs.

For programs that use '`{`' and '`}`' in regexp constants, it is good practice to always escape them with a backslash. Then the regexp constants are valid and work the way you want them to, using any version of `awk`.[2]

Finally, when '`{`' and '`}`' appear in regexp constants in a way that cannot be interpreted as an interval expression (such as `/q{a}/`), then they stand for themselves.

In regular expressions, the '`*`', '`+`', and '`?`' operators, as well as the braces '`{`' and '`}`', have the highest precedence, followed by concatenation, and finally by '`|`'. As in arithmetic, parentheses can change how operators are grouped.

In POSIX `awk` and `gawk`, the '`*`', '`+`', and '`?`' operators stand for themselves when there is nothing in the regexp that precedes them. For example, `/+/` matches a literal plus sign. However, many other versions of `awk` treat such a usage as a syntax error.

If `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), interval expressions are not available in regular expressions.

[2] Use two backslashes if you're using a string constant with a regexp operator or function.

3.4 Using Bracket Expressions

As mentioned earlier, a bracket expression matches any character amongst those listed between the opening and closing square brackets.

Within a bracket expression, a *range expression* consists of two characters separated by a hyphen. It matches any single character that sorts between the two characters, based upon the system's native character set. For example, '`[0-9]`' is equivalent to '`[0123456789]`'. (See Section A.7 [Regexp Ranges and Locales: A Long Sad Story], page 394, for an explanation of how the POSIX standard and `gawk` have changed over time. This is mainly of historical interest.)

To include one of the characters '\', '`]`', '`-`', or '`^`' in a bracket expression, put a '\' in front of it. For example:

```
[d\]]
```

matches either '`d`' or '`]`'.

This treatment of '\' in bracket expressions is compatible with other `awk` implementations and is also mandated by POSIX. The regular expressions in `awk` are a superset of the POSIX specification for Extended Regular Expressions (EREs). POSIX EREs are based on the regular expressions accepted by the traditional `egrep` utility.

Character classes are a feature introduced in the POSIX standard. A character class is a special notation for describing lists of characters that have a specific attribute, but the actual characters can vary from country to country and/or from character set to character set. For example, the notion of what is an alphabetic character differs between the United States and France.

A character class is only valid in a regexp *inside* the brackets of a bracket expression. Character classes consist of '`[:`', a keyword denoting the class, and '`:]`'. Table 3.1 lists the character classes defined by the POSIX standard.

Class	**Meaning**
`[:alnum:]`	Alphanumeric characters.
`[:alpha:]`	Alphabetic characters.
`[:blank:]`	Space and TAB characters.
`[:cntrl:]`	Control characters.
`[:digit:]`	Numeric characters.
`[:graph:]`	Characters that are both printable and visible. (A space is printable but not visible, whereas an '`a`' is both.)
`[:lower:]`	Lowercase alphabetic characters.
`[:print:]`	Printable characters (characters that are not control characters).
`[:punct:]`	Punctuation characters (characters that are not letters, digits, control characters, or space characters).
`[:space:]`	Space characters (such as space, TAB, and formfeed, to name a few).
`[:upper:]`	Uppercase alphabetic characters.
`[:xdigit:]`	Characters that are hexadecimal digits.

Table 3.1: POSIX Character Classes

For example, before the POSIX standard, you had to write `/[A-Za-z0-9]/` to match alphanumeric characters. If your character set had other alphabetic characters in it, this would not match them. With the POSIX character classes, you can write `/[[:alnum:]]/` to match the alphabetic and numeric characters in your character set.

Two additional special sequences can appear in bracket expressions. These apply to non-ASCII character sets, which can have single symbols (called *collating elements*) that are represented with more than one character. They can also have several characters that are equivalent for *collating*, or sorting, purposes. (For example, in French, a plain "e" and a grave-accented "è" are equivalent.) These sequences are:

Collating symbols
: Multicharacter collating elements enclosed between '`[.`' and '`.]`'. For example, if '`ch`' is a collating element, then `[[.ch.]]` is a regexp that matches this collating element, whereas `[ch]` is a regexp that matches either '`c`' or '`h`'.

Equivalence classes
: Locale-specific names for a list of characters that are equal. The name is enclosed between '`[=`' and '`=]`'. For example, the name '`e`' might be used to represent all of "e," "è," and "é." In this case, `[[=e=]]` is a regexp that matches any of '`e`', '`é`', or '`è`'.

These features are very valuable in non-English-speaking locales.

> **CAUTION:** The library functions that `gawk` uses for regular expression matching currently recognize only POSIX character classes; they do not recognize collating symbols or equivalence classes.

3.5 `gawk`-Specific Regexp Operators

GNU software that deals with regular expressions provides a number of additional regexp operators. These operators are described in this section and are specific to `gawk`; they are not available in other `awk` implementations. Most of the additional operators deal with word matching. For our purposes, a *word* is a sequence of one or more letters, digits, or underscores ('`_`'):

`\s` : Matches any whitespace character. Think of it as shorthand for `[[:space:]]`.

`\S` : Matches any character that is not whitespace. Think of it as shorthand for `[^[:space:]]`.

`\w` : Matches any word-constituent character—that is, it matches any letter, digit, or underscore. Think of it as shorthand for `[[:alnum:]_]`.

`\W` : Matches any character that is not word-constituent. Think of it as shorthand for `[^[:alnum:]_]`.

`\<` : Matches the empty string at the beginning of a word. For example, `/\<away/` matches '`away`' but not '`stowaway`'.

`\>` : Matches the empty string at the end of a word. For example, `/stow\>/` matches '`stow`' but not '`stowaway`'.

`\y` : Matches the empty string at either the beginning or the end of a word (i.e., the word boundar**y**). For example, '`\yballs?\y`' matches either '`ball`' or '`balls`', as a separate word.

`\B` Matches the empty string that occurs between two word-constituent characters. For example, `/\Brat\B/` matches '`crate`' but it does not match '`dirty rat`'. '`\B`' is essentially the opposite of '`\y`'.

There are two other operators that work on buffers. In Emacs, a *buffer* is, naturally, an Emacs buffer. For other programs, `gawk`'s regexp library routines consider the entire string to match as the buffer. The operators are:

`` \` `` Matches the empty string at the beginning of a buffer (string).

`\'` Matches the empty string at the end of a buffer (string).

Because '`^`' and '`$`' always work in terms of the beginning and end of strings, these operators don't add any new capabilities for `awk`. They are provided for compatibility with other GNU software.

In other GNU software, the word-boundary operator is '`\b`'. However, that conflicts with the `awk` language's definition of '`\b`' as backspace, so `gawk` uses a different letter. An alternative method would have been to require two backslashes in the GNU operators, but this was deemed too confusing. The current method of using '`\y`' for the GNU '`\b`' appears to be the lesser of two evils.

The various command-line options (see Section 2.2 [Command-Line Options], page 29) control how `gawk` interprets characters in regexps:

No options
: In the default case, `gawk` provides all the facilities of POSIX regexps and the previously described GNU regexp operators.

`--posix` Only POSIX regexps are supported; the GNU operators are not special (e.g., '`\w`' matches a literal '`w`'). Interval expressions are allowed.

`--traditional`
: Traditional Unix `awk` regexps are matched. The GNU operators are not special, and interval expressions are not available. The POSIX character classes (`[[:alnum:]]`, etc.) are supported, as Brian Kernighan's `awk` does support them. Characters described by octal and hexadecimal escape sequences are treated literally, even if they represent regexp metacharacters.

`--re-interval`
: Allow interval expressions in regexps, if `--traditional` has been provided. Otherwise, interval expressions are available by default.

3.6 Case Sensitivity in Matching

Case is normally significant in regular expressions, both when matching ordinary characters (i.e., not metacharacters) and inside bracket expressions. Thus, a '`w`' in a regular expression matches only a lowercase '`w`' and not an uppercase '`W`'.

The simplest way to do a case-independent match is to use a bracket expression—for example, '`[Ww]`'. However, this can be cumbersome if you need to use it often, and it can make the regular expressions harder to read. There are two alternatives that you might prefer.

One way to perform a case-insensitive match at a particular point in the program is to convert the data to a single case, using the `tolower()` or `toupper()` built-in string functions (which we haven't discussed yet; see Section 9.1.3 [String-Manipulation Functions], page 161). For example:

```
tolower($1) ~ /foo/  { ... }
```

converts the first field to lowercase before matching against it. This works in any POSIX-compliant `awk`.

Another method, specific to `gawk`, is to set the variable `IGNORECASE` to a nonzero value (see Section 7.5 [Built-in Variables], page 134). When `IGNORECASE` is not zero, *all* regexp and string operations ignore case. Changing the value of `IGNORECASE` dynamically controls the case-sensitivity of the program as it runs. Case is significant by default because `IGNORECASE` (like most variables) is initialized to zero:

```
x = "aB"
if (x ~ /ab/) ...   # this test will fail

IGNORECASE = 1
if (x ~ /ab/) ...   # now it will succeed
```

In general, you cannot use `IGNORECASE` to make certain rules case-insensitive and other rules case-sensitive, because there is no straightforward way to set `IGNORECASE` just for the pattern of a particular rule.[3] To do this, use either bracket expressions or `tolower()`. However, one thing you can do with `IGNORECASE` only is dynamically turn case-sensitivity on or off for all the rules at once.

`IGNORECASE` can be set on the command line or in a `BEGIN` rule (see Section 2.3 [Other Command-Line Arguments], page 35; also see Section 7.1.4.1 [Startup and Cleanup Actions], page 122). Setting `IGNORECASE` from the command line is a way to make a program case-insensitive without having to edit it.

Both regexp and string comparison operations are affected by `IGNORECASE`.

In multibyte locales, the equivalences between upper- and lowercase characters are tested based on the wide-character values of the locale's character set. Otherwise, the characters are tested based on the ISO-8859-1 (ISO Latin-1) character set. This character set is a superset of the traditional 128 ASCII characters, which also provides a number of characters suitable for use with European languages.[4]

The value of `IGNORECASE` has no effect if `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29). Case is always significant in compatibility mode.

3.7 How Much Text Matches?

Consider the following:

```
echo aaaabcd | awk '{ sub(/a+/, "<A>"); print }'
```

---

[3] Experienced C and C++ programmers will note that it is possible, using something like '`IGNORECASE = 1 && /foObAr/ { ... }`' and '`IGNORECASE = 0 || /foobar/ { ... }`'. However, this is somewhat obscure and we don't recommend it.

[4] If you don't understand this, don't worry about it; it just means that `gawk` does the right thing.

This example uses the `sub()` function (which we haven't discussed yet; see Section 9.1.3 [String-Manipulation Functions], page 161) to make a change to the input record. Here, the regexp `/a+/` indicates "one or more '`a`' characters," and the replacement text is '`<A>`'.

The input contains four '`a`' characters. `awk` (and POSIX) regular expressions always match the leftmost, *longest* sequence of input characters that can match. Thus, all four '`a`' characters are replaced with '`<A>`' in this example:

```
$ echo aaaabcd | awk '{ sub(/a+/, "<A>"); print }'
⊣ <A>bcd
```

For simple match/no-match tests, this is not so important. But when doing text matching and substitutions with the `match()`, `sub()`, `gsub()`, and `gensub()` functions, it is very important. Understanding this principle is also important for regexp-based record and field splitting (see Section 4.1 [How Input Is Split into Records], page 55, and also see Section 4.5 [Specifying How Fields Are Separated], page 62).

3.8 Using Dynamic Regexps

The righthand side of a '`~`' or '`!~`' operator need not be a regexp constant (i.e., a string of characters between slashes). It may be any expression. The expression is evaluated and converted to a string if necessary; the contents of the string are then used as the regexp. A regexp computed in this way is called a *dynamic regexp*:

```
BEGIN { digits_regexp = "[[:digit:]]+" }
$0 ~ digits_regexp    { print }
```

This sets `digits_regexp` to a regexp that describes one or more digits, and tests whether the input record matches this regexp.

> **NOTE:** When using the '`~`' and '`!~`' operators, there is a difference between a regexp constant enclosed in slashes and a string constant enclosed in double quotes. If you are going to use a string constant, you have to understand that the string is, in essence, scanned *twice*: the first time when `awk` reads your program, and the second time when it goes to match the string on the lefthand side of the operator with the pattern on the right. This is true of any string-valued expression (such as `digits_regexp`, shown previously), not just string constants.

What difference does it make if the string is scanned twice? The answer has to do with escape sequences, and particularly with backslashes. To get a backslash into a regular expression inside a string, you have to type two backslashes.

For example, `/\*/` is a regexp constant for a literal '`*`'. Only one backslash is needed. To do the same thing with a string, you have to type `"\\*"`. The first backslash escapes the second one so that the string actually contains the two characters '`\`' and '`*`'.

Given that you can use both regexp and string constants to describe regular expressions, which should you use? The answer is "regexp constants," for several reasons:

- String constants are more complicated to write and more difficult to read. Using regexp constants makes your programs less error-prone. Not understanding the difference between the two kinds of constants is a common source of errors.
- It is more efficient to use regexp constants. `awk` can note that you have supplied a regexp and store it internally in a form that makes pattern matching more efficient.

When using a string constant, awk must first convert the string into this internal form and then perform the pattern matching.

- Using regexp constants is better form; it shows clearly that you intend a regexp match.

Using \n in Bracket Expressions of Dynamic Regexps

Some commercial versions of awk do not allow the newline character to be used inside a bracket expression for a dynamic regexp:

```
$ awk '$0 ~ "[ \t\n]"'
error  awk: newline in character class [
error  ]...
error   source line number 1
error   context is
error          >>>  <<<
```

But a newline in a regexp constant works with no problem:

```
$ awk '$0 ~ /[ \t\n]/'
here is a sample line
⊣ here is a sample line
Ctrl-d
```

gawk does not have this problem, and it isn't likely to occur often in practice, but it's worth noting for future reference.

4 Reading Input Files

In the typical `awk` program, `awk` reads all input either from the standard input (by default, this is the keyboard, but often it is a pipe from another command) or from files whose names you specify on the `awk` command line. If you specify input files, `awk` reads them in order, processing all the data from one before going on to the next. The name of the current input file can be found in the built-in variable `FILENAME` (see Section 7.5 [Built-in Variables], page 134).

The input is read in units called *records*, and is processed by the rules of your program one record at a time. By default, each record is one line. Each record is automatically split into chunks called *fields*. This makes it more convenient for programs to work on the parts of a record.

On rare occasions, you may need to use the `getline` command. The `getline` command is valuable, both because it can do explicit input from any number of files, and because the files used with it do not have to be named on the `awk` command line (see Section 4.9 [Explicit Input with `getline`], page 73).

4.1 How Input Is Split into Records

The `awk` utility divides the input for your `awk` program into records and fields. `awk` keeps track of the number of records that have been read so far from the current input file. This value is stored in a built-in variable called `FNR`. It is reset to zero when a new file is started. Another built-in variable, `NR`, records the total number of input records read so far from all data files. It starts at zero, but is never automatically reset to zero.

Records are separated by a character called the *record separator*. By default, the record separator is the newline character. This is why records are, by default, single lines. A different character can be used for the record separator by assigning the character to the built-in variable `RS`.

Like any other variable, the value of `RS` can be changed in the `awk` program with the assignment operator, '`=`' (see Section 6.2.3 [Assignment Expressions], page 106). The new record-separator character should be enclosed in quotation marks, which indicate a string constant. Often the right time to do this is at the beginning of execution, before any input is processed, so that the very first record is read with the proper separator. To do this, use the special `BEGIN` pattern (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122). For example:

```
awk 'BEGIN { RS = "/" }
     { print $0 }' BBS-list
```

changes the value of `RS` to `"/"`, before reading any input. This is a string whose first character is a slash; as a result, records are separated by slashes. Then the input file is read, and the second rule in the `awk` program (the action with no pattern) prints each record. Because each `print` statement adds a newline at the end of its output, this `awk` program copies the input with each slash changed to a newline. Here are the results of running the program on `BBS-list`:

```
$ awk 'BEGIN { RS = "/" }
>       { print $0 }' BBS-list
⊣ aardvark     555-5553     1200
```

```
⊣ 300           B
⊣ alpo-net      555-3412     2400
⊣ 1200
⊣ 300     A
⊣ barfly        555-7685     1200
⊣ 300           A
⊣ bites         555-1675     2400
⊣ 1200
⊣ 300     A
⊣ camelot       555-0542     300               C
⊣ core          555-2912     1200
⊣ 300           C
⊣ fooey         555-1234     2400
⊣ 1200
⊣ 300     B
⊣ foot          555-6699     1200
⊣ 300           B
⊣ macfoo        555-6480     1200
⊣ 300           A
⊣ sdace         555-3430     2400
⊣ 1200
⊣ 300     A
⊣ sabafoo       555-2127     1200
⊣ 300           C
⊣
```

Note that the entry for the 'camelot' BBS is not split. In the original data file (see Section 1.2 [Data Files for the Examples], page 20), the line looks like this:

```
camelot      555-0542     300               C
```

It has one baud rate only, so there are no slashes in the record, unlike the others which have two or more baud rates. In fact, this record is treated as part of the record for the 'core' BBS; the newline separating them in the output is the original newline in the data file, not the one added by awk when it printed the record!

Another way to change the record separator is on the command line, using the variable-assignment feature (see Section 2.3 [Other Command-Line Arguments], page 35):

```
awk '{ print $0 }' RS="/" BBS-list
```

This sets RS to '/' before processing BBS-list.

Using an unusual character such as '/' for the record separator produces correct behavior in the vast majority of cases.

There is one unusual case, that occurs when gawk is being fully POSIX-compliant (see Section 2.2 [Command-Line Options], page 29). Then, the following (extreme) pipeline prints a surprising '1':

```
$ echo | gawk --posix 'BEGIN { RS = "a" } ; { print NF }'
⊣ 1
```

There is one field, consisting of a newline. The value of the built-in variable `NF` is the number of fields in the current record. (In the normal case, `gawk` treats the newline as whitespace, printing '`0`' as the result. Most other versions of `awk` also act this way.)

Reaching the end of an input file terminates the current input record, even if the last character in the file is not the character in `RS`.

The empty string `""` (a string without any characters) has a special meaning as the value of `RS`. It means that records are separated by one or more blank lines and nothing else. See Section 4.8 [Multiple-Line Records], page 71, for more details.

If you change the value of `RS` in the middle of an `awk` run, the new value is used to delimit subsequent records, but the record currently being processed, as well as records already processed, are not affected.

After the end of the record has been determined, `gawk` sets the variable `RT` to the text in the input that matched `RS`.

When using `gawk`, the value of `RS` is not limited to a one-character string. It can be any regular expression (see Chapter 3 [Regular Expressions], page 43). (c.e.) In general, each record ends at the next string that matches the regular expression; the next record starts at the end of the matching string. This general rule is actually at work in the usual case, where `RS` contains just a newline: a record ends at the beginning of the next matching string (the next newline in the input), and the following record starts just after the end of this string (at the first character of the following line). The newline, because it matches `RS`, is not part of either record.

When `RS` is a single character, `RT` contains the same single character. However, when `RS` is a regular expression, `RT` contains the actual input text that matched the regular expression.

If the input file ended without any text that matches `RS`, `gawk` sets `RT` to the null string.

The following example illustrates both of these features. It sets `RS` equal to a regular expression that matches either a newline or a series of one or more uppercase letters with optional leading and/or trailing whitespace:

```
$ echo record 1 AAAA record 2 BBBB record 3 |
> gawk 'BEGIN { RS = "\n|( *[[:upper:]]+ *)" }
>             { print "Record =", $0, "and RT =", RT }'
⊣ Record = record 1 and RT =  AAAA
⊣ Record = record 2 and RT =  BBBB
⊣ Record = record 3 and RT =
⊣
```

The final line of output has an extra blank line. This is because the value of `RT` is a newline, and the `print` statement supplies its own terminating newline. See Section 11.3.8 [A Simple Stream Editor], page 264, for a more useful example of `RS` as a regexp and `RT`.

If you set `RS` to a regular expression that allows optional trailing text, such as '`RS = "abc(XYZ)?"`' it is possible, due to implementation constraints, that `gawk` may match the leading part of the regular expression, but not the trailing part, particularly if the input text that could match the trailing part is fairly long. `gawk` attempts to avoid this problem, but currently, there's no guarantee that this will never happen.

> **NOTE:** Remember that in `awk`, the '`^`' and '`$`' anchor metacharacters match the beginning and end of a *string*, and not the beginning and end of a *line*. As a

result, something like ‘`RS = "^[[:upper:]]"`’ can only match at the beginning of a file. This is because `gawk` views the input file as one long string that happens to contain newline characters in it. It is thus best to avoid anchor characters in the value of `RS`.

The use of `RS` as a regular expression and the `RT` variable are `gawk` extensions; they are not available in compatibility mode (see Section 2.2 [Command-Line Options], page 29). In compatibility mode, only the first character of the value of `RS` is used to determine the end of the record.

`RS = "\0"` Is Not Portable

There are times when you might want to treat an entire data file as a single record. The only way to make this happen is to give `RS` a value that you know doesn’t occur in the input file. This is hard to do in a general way, such that a program always works for arbitrary input files.

You might think that for text files, the NUL character, which consists of a character with all bits equal to zero, is a good value to use for `RS` in this case:

```
BEGIN { RS = "\0" }  # whole file becomes one record?
```

`gawk` in fact accepts this, and uses the NUL character for the record separator. However, this usage is *not* portable to other `awk` implementations.

All other `awk` implementations[1] store strings internally as C-style strings. C strings use the NUL character as the string terminator. In effect, this means that ‘`RS = "\0"`’ is the same as ‘`RS = ""`’.

The best way to treat a whole file as a single record is to simply read the file in, one record at a time, concatenating each record onto the end of the previous ones.

4.2 Examining Fields

When `awk` reads an input record, the record is automatically *parsed* or separated by the `awk` utility into chunks called *fields*. By default, fields are separated by *whitespace*, like words in a line. Whitespace in `awk` means any string of one or more spaces, TABs, or newlines;[2] other characters, such as formfeed, vertical tab, etc., that are considered whitespace by other languages, are *not* considered whitespace by `awk`.

The purpose of fields is to make it more convenient for you to refer to these pieces of the record. You don’t have to use them—you can operate on the whole record if you want—but fields are what make simple `awk` programs so powerful.

A dollar-sign (‘`$`’) is used to refer to a field in an `awk` program, followed by the number of the field you want. Thus, `$1` refers to the first field, `$2` to the second, and so on. (Unlike the Unix shells, the field numbers are not limited to single digits. `$127` is the one hundred twenty-seventh field in the record.) For example, suppose the following is a line of input:

```
This seems like a pretty nice example.
```

---

[1] At least that we know about.

[2] In POSIX `awk`, newlines are not considered whitespace for separating fields.

Here the first field, or `$1`, is '`This`', the second field, or `$2`, is '`seems`', and so on. Note that the last field, `$7`, is '`example.`'. Because there is no space between the '`e`' and the '`.`', the period is considered part of the seventh field.

`NF` is a built-in variable whose value is the number of fields in the current record. `awk` automatically updates the value of `NF` each time it reads a record. No matter how many fields there are, the last field in a record can be represented by `$NF`. So, `$NF` is the same as `$7`, which is '`example.`'. If you try to reference a field beyond the last one (such as `$8` when the record has only seven fields), you get the empty string. (If used in a numeric operation, you get zero.)

The use of `$0`, which looks like a reference to the "zero-th" field, is a special case: it represents the whole input record when you are not interested in specific fields. Here are some more examples:

```
$ awk '$1 ~ /foo/ { print $0 }' BBS-list
⊣ fooey        555-1234     2400/1200/300     B
⊣ foot         555-6699     1200/300          B
⊣ macfoo       555-6480     1200/300          A
⊣ sabafoo      555-2127     1200/300          C
```

This example prints each record in the file `BBS-list` whose first field contains the string '`foo`'. The operator '`~`' is called a *matching operator* (see Section 3.1 [How to Use Regular Expressions], page 43); it tests whether a string (here, the field `$1`) matches a given regular expression.

By contrast, the following example looks for '`foo`' in *the entire record* and prints the first field and the last field for each matching input record:

```
$ awk '/foo/ { print $1, $NF }' BBS-list
⊣ fooey B
⊣ foot B
⊣ macfoo A
⊣ sabafoo C
```

4.3 Nonconstant Field Numbers

The number of a field does not need to be a constant. Any expression in the `awk` language can be used after a '`$`' to refer to a field. The value of the expression specifies the field number. If the value is a string, rather than a number, it is converted to a number. Consider this example:

```
awk '{ print $NR }'
```

Recall that `NR` is the number of records read so far: one in the first record, two in the second, etc. So this example prints the first field of the first record, the second field of the second record, and so on. For the twentieth record, field number 20 is printed; most likely, the record has fewer than 20 fields, so this prints a blank line. Here is another example of using expressions as field numbers:

```
awk '{ print $(2*2) }' BBS-list
```

`awk` evaluates the expression '`(2*2)`' and uses its value as the number of the field to print. The '`*`' sign represents multiplication, so the expression '`2*2`' evaluates to four. The parentheses are used so that the multiplication is done before the '`$`' operation; they are necessary whenever there is a binary operator in the field-number expression. This example, then, prints the hours of operation (the fourth field) for every line of the file `BBS-list`. (All of the `awk` operators are listed, in order of decreasing precedence, in Section 6.5 [Operator Precedence (How Operators Nest)], page 117.)

If the field number you compute is zero, you get the entire record. Thus, '`$(2-2)`' has the same value as `$0`. Negative field numbers are not allowed; trying to reference one usually terminates the program. (The POSIX standard does not define what happens when you reference a negative field number. `gawk` notices this and terminates your program. Other `awk` implementations may behave differently.)

As mentioned in Section 4.2 [Examining Fields], page 58, `awk` stores the current record's number of fields in the built-in variable `NF` (also see Section 7.5 [Built-in Variables], page 134). The expression `$NF` is not a special feature—it is the direct consequence of evaluating `NF` and using its value as a field number.

4.4 Changing the Contents of a Field

The contents of a field, as seen by `awk`, can be changed within an `awk` program; this changes what `awk` perceives as the current input record. (The actual input is untouched; `awk` *never* modifies the input file.) Consider the following example and its output:

```
$ awk '{ nboxes = $3 ; $3 = $3 - 10
>        print nboxes, $3 }' inventory-shipped
⊣ 25 15
⊣ 32 22
⊣ 24 14
...
```

The program first saves the original value of field three in the variable `nboxes`. The '`-`' sign represents subtraction, so this program reassigns field three, `$3`, as the original value of field three minus ten: '`$3 - 10`'. (See Section 6.2.1 [Arithmetic Operators], page 103.) Then it prints the original and new values for field three. (Someone in the warehouse made a consistent mistake while inventorying the red boxes.)

For this to work, the text in field `$3` must make sense as a number; the string of characters must be converted to a number for the computer to do arithmetic on it. The number resulting from the subtraction is converted back to a string of characters that then becomes field three. See Section 6.1.4 [Conversion of Strings and Numbers], page 101.

When the value of a field is changed (as perceived by `awk`), the text of the input record is recalculated to contain the new field where the old one was. In other words, `$0` changes to reflect the altered field. Thus, this program prints a copy of the input file, with 10 subtracted from the second field of each line:

```
$ awk '{ $2 = $2 - 10; print $0 }' inventory-shipped
⊣ Jan 3 25 15 115
⊣ Feb 5 32 24 226
⊣ Mar 5 24 34 228
...
```

It is also possible to also assign contents to fields that are out of range. For example:

```
$ awk '{ $6 = ($5 + $4 + $3 + $2)
```

```
>         print $6 }' inventory-shipped
⊣ 168
⊣ 297
⊣ 301
...
```

We've just created `$6`, whose value is the sum of fields `$2`, `$3`, `$4`, and `$5`. The '`+`' sign represents addition. For the file `inventory-shipped`, `$6` represents the total number of parcels shipped for a particular month.

Creating a new field changes `awk`'s internal copy of the current input record, which is the value of `$0`. Thus, if you do '`print $0`' after adding a field, the record printed includes the new field, with the appropriate number of field separators between it and the previously existing fields.

This recomputation affects and is affected by `NF` (the number of fields; see Section 4.2 [Examining Fields], page 58). For example, the value of `NF` is set to the number of the highest field you create. The exact format of `$0` is also affected by a feature that has not been discussed yet: the *output field separator*, `OFS`, used to separate the fields (see Section 5.3 [Output Separators], page 83).

Note, however, that merely *referencing* an out-of-range field does *not* change the value of either `$0` or `NF`. Referencing an out-of-range field only produces an empty string. For example:

```
if ($(NF+1) != "")
    print "can't happen"
else
    print "everything is normal"
```

should print '`everything is normal`', because `NF+1` is certain to be out of range. (See Section 7.4.1 [The `if-else` Statement], page 126, for more information about `awk`'s `if-else` statements. See Section 6.3.2 [Variable Typing and Comparison Expressions], page 110, for more information about the '`!=`' operator.)

It is important to note that making an assignment to an existing field changes the value of `$0` but does not change the value of `NF`, even when you assign the empty string to a field. For example:

```
$ echo a b c d | awk '{ OFS = ":"; $2 = ""
>                       print $0; print NF }'
⊣ a::c:d
⊣ 4
```

The field is still there; it just has an empty value, denoted by the two colons between '`a`' and '`c`'. This example shows what happens if you create a new field:

```
$ echo a b c d | awk '{ OFS = ":"; $2 = ""; $6 = "new"
>                       print $0; print NF }'
⊣ a::c:d::new
⊣ 6
```

The intervening field, `$5`, is created with an empty value (indicated by the second pair of adjacent colons), and `NF` is updated with the value six.

Decrementing `NF` throws away the values of the fields after the new value of `NF` and recomputes `$0`. Here is an example:

```
$ echo a b c d e f | awk '{ print "NF =", NF;
>                             NF = 3; print $0 }'
⊣ NF = 6
⊣ a b c
```

CAUTION: Some versions of `awk` don't rebuild `$0` when `NF` is decremented. Caveat emptor.

Finally, there are times when it is convenient to force `awk` to rebuild the entire record, using the current value of the fields and `OFS`. To do this, use the seemingly innocuous assignment:

```
$1 = $1   # force record to be reconstituted
print $0  # or whatever else with $0
```

This forces `awk` to rebuild the record. It does help to add a comment, as we've shown here.

There is a flip side to the relationship between `$0` and the fields. Any assignment to `$0` causes the record to be reparsed into fields using the *current* value of `FS`. This also applies to any built-in function that updates `$0`, such as `sub()` and `gsub()` (see Section 9.1.3 [String-Manipulation Functions], page 161).

Understanding `$0`

It is important to remember that `$0` is the *full* record, exactly as it was read from the input. This includes any leading or trailing whitespace, and the exact whitespace (or other characters) that separate the fields.

It is a not-uncommon error to try to change the field separators in a record simply by setting `FS` and `OFS`, and then expecting a plain '`print`' or '`print $0`' to print the modified record.

But this does not work, since nothing was done to change the record itself. Instead, you must force the record to be rebuilt, typically with a statement such as '`$1 = $1`', as described earlier.

4.5 Specifying How Fields Are Separated

The *field separator*, which is either a single character or a regular expression, controls the way `awk` splits an input record into fields. `awk` scans the input record for character sequences that match the separator; the fields themselves are the text between the matches.

In the examples that follow, we use the bullet symbol (•) to represent spaces in the output. If the field separator is '`oo`', then the following line:

```
moo goo gai pan
```

is split into three fields: '`m`', '`•g`', and '`•gai•pan`'. Note the leading spaces in the values of the second and third fields.

The field separator is represented by the built-in variable `FS`. Shell programmers take note: `awk` does *not* use the name `IFS` that is used by the POSIX-compliant shells (such as the Unix Bourne shell, `sh`, or Bash).

The value of `FS` can be changed in the `awk` program with the assignment operator, '`=`' (see Section 6.2.3 [Assignment Expressions], page 106). Often the right time to do this is at the beginning of execution before any input has been processed, so that the very first record is read with the proper separator. To do this, use the special `BEGIN` pattern (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122). For example, here we set the value of `FS` to the string `","`:

```
awk 'BEGIN { FS = "," } ; { print $2 }'
```

Given the input line:

```
John Q. Smith, 29 Oak St., Walamazoo, MI 42139
```

this `awk` program extracts and prints the string '`•29•Oak•St.`'.

Sometimes the input data contains separator characters that don't separate fields the way you thought they would. For instance, the person's name in the example we just used might have a title or suffix attached, such as:

```
John Q. Smith, LXIX, 29 Oak St., Walamazoo, MI 42139
```

The same program would extract '`•LXIX`', instead of '`•29•Oak•St.`'. If you were expecting the program to print the address, you would be surprised. The moral is to choose your data layout and separator characters carefully to prevent such problems. (If the data is not in a form that is easy to process, perhaps you can massage it first with a separate `awk` program.)

4.5.1 Whitespace Normally Separates Fields

Fields are normally separated by whitespace sequences (spaces, TABs, and newlines), not by single spaces. Two spaces in a row do not delimit an empty field. The default value of the field separator `FS` is a string containing a single space, `" "`. If `awk` interpreted this value in the usual way, each space character would separate fields, so two spaces in a row would make an empty field between them. The reason this does not happen is that a single space as the value of `FS` is a special case—it is taken to specify the default manner of delimiting fields.

If `FS` is any other single character, such as `","`, then each occurrence of that character separates two fields. Two consecutive occurrences delimit an empty field. If the character occurs at the beginning or the end of the line, that too delimits an empty field. The space character is the only single character that does not follow these rules.

4.5.2 Using Regular Expressions to Separate Fields

The previous subsection discussed the use of single characters or simple strings as the value of `FS`. More generally, the value of `FS` may be a string containing any regular expression. In this case, each match in the record for the regular expression separates fields. For example, the assignment:

```
FS = ", \t"
```

makes every area of an input line that consists of a comma followed by a space and a TAB into a field separator.

For a less trivial example of a regular expression, try using single spaces to separate fields the way single commas are used. `FS` can be set to `"[ ]"` (left bracket, space, right bracket). This regular expression matches a single space and nothing else (see Chapter 3 [Regular Expressions], page 43).

There is an important difference between the two cases of '`FS = " "`' (a single space) and '`FS = "[ \t\n]+"`' (a regular expression matching one or more spaces, TABs, or newlines). For both values of `FS`, fields are separated by *runs* (multiple adjacent occurrences) of spaces, TABs, and/or newlines. However, when the value of FS is `" "`, `awk` first strips leading and trailing whitespace from the record and then decides where the fields are. For example, the following pipeline prints '`b`':

```
$ echo ' a b c d ' | awk '{ print $2 }'
⊣ b
```

However, this pipeline prints '`a`' (note the extra spaces around each letter):

```
$ echo ' a  b  c  d ' | awk 'BEGIN { FS = "[ \t\n]+" }
>                                   { print $2 }'
⊣ a
```

In this case, the first field is *null* or empty.

The stripping of leading and trailing whitespace also comes into play whenever `$0` is recomputed. For instance, study this pipeline:

```
$ echo '   a b c d' | awk '{ print; $2 = $2; print }'
⊣    a b c d
⊣ a b c d
```

The first `print` statement prints the record as it was read, with leading whitespace intact. The assignment to `$2` rebuilds `$0` by concatenating `$1` through `$NF` together, separated by the value of `OFS`. Because the leading whitespace was ignored when finding `$1`, it is not part of the new `$0`. Finally, the last `print` statement prints the new `$0`.

There is an additional subtlety to be aware of when using regular expressions for field splitting. It is not well-specified in the POSIX standard, or anywhere else, what '`^`' means when splitting fields. Does the '`^`' match only at the beginning of the entire record? Or is each field separator a new string? It turns out that different `awk` versions answer this question differently, and you should not rely on any specific behavior in your programs.

As a point of information, Brian Kernighan's `awk` allows '`^`' to match only at the beginning of the record. `gawk` also works this way. For example:

```
$ echo 'xxAA  xxBxx  C' |
> gawk -F '(^x+)|( +)' '{ for (i = 1; i <= NF; i++)
>                                   printf "-->%s<--\n", $i }'
⊣ --><--
⊣ -->AA<--
⊣ -->xxBxx<--
⊣ -->C<--
```

4.5.3 Making Each Character a Separate Field

There are times when you may want to examine each character of a record separately. This can be done in `gawk` by simply assigning the null string (`""`) to `FS`. (c.e.) In this case, each individual character in the record becomes a separate field. For example:

```
$ echo a b | gawk 'BEGIN { FS = "" }
>                  {
>                      for (i = 1; i <= NF; i = i + 1)
>                          print "Field", i, "is", $i
>                  }'
⊣ Field 1 is a
```

```
⊣ Field 2 is
⊣ Field 3 is b
```

Traditionally, the behavior of `FS` equal to `""` was not defined. In this case, most versions of Unix `awk` simply treat the entire record as only having one field. In compatibility mode (see Section 2.2 [Command-Line Options], page 29), if `FS` is the null string, then `gawk` also behaves this way.

4.5.4 Setting FS from the Command Line

`FS` can be set on the command line. Use the `-F` option to do so. For example:

```
awk -F, 'program' input-files
```

sets `FS` to the '`,`' character. Notice that the option uses an uppercase '`F`' instead of a lowercase '`f`'. The latter option (`-f`) specifies a file containing an `awk` program. Case is significant in command-line options: the `-F` and `-f` options have nothing to do with each other. You can use both options at the same time to set the `FS` variable *and* get an `awk` program from a file.

The value used for the argument to `-F` is processed in exactly the same way as assignments to the built-in variable `FS`. Any special characters in the field separator must be escaped appropriately. For example, to use a '\' as the field separator on the command line, you would have to type:

```
# same as FS = "\\"
awk -F\\\\ '...' files ...
```

Because '\' is used for quoting in the shell, `awk` sees '`-F\\`'. Then `awk` processes the '`\\`' for escape characters (see Section 3.2 [Escape Sequences], page 44), finally yielding a single '\' to use for the field separator.

As a special case, in compatibility mode (see Section 2.2 [Command-Line Options], page 29), if the argument to `-F` is '`t`', then `FS` is set to the TAB character. If you type '`-F\t`' at the shell, without any quotes, the '\' gets deleted, so `awk` figures that you really want your fields to be separated with TABs and not '`t`'s. Use '`-v FS="t"`' or '`-F"[t]"`' on the command line if you really do want to separate your fields with '`t`'s.

As an example, let's use an `awk` program file called `baud.awk` that contains the pattern `/300/` and the action '`print $1`':

```
/300/   { print $1 }
```

Let's also set `FS` to be the '`-`' character and run the program on the file `BBS-list`. The following command prints a list of the names of the bulletin boards that operate at 300 baud and the first three digits of their phone numbers:

```
$ awk -F- -f baud.awk BBS-list
⊣ aardvark     555
⊣ alpo
⊣ barfly       555
⊣ bites        555
⊣ camelot      555
⊣ core         555
⊣ fooey        555
⊣ foot         555
```

```
⊣ macfoo       555
⊣ sdace        555
⊣ sabafoo      555
```

Note the second line of output. The second line in the original file looked like this:

```
alpo-net     555-3412     2400/1200/300     A
```

The '-' as part of the system's name was used as the field separator, instead of the '-' in the phone number that was originally intended. This demonstrates why you have to be careful in choosing your field and record separators.

Perhaps the most common use of a single character as the field separator occurs when processing the Unix system password file. On many Unix systems, each user has a separate entry in the system password file, one line per user. The information in these lines is separated by colons. The first field is the user's login name and the second is the user's (encrypted or shadow) password. A password file entry might look like this:

```
arnold:xyzzy:2076:10:Arnold Robbins:/home/arnold:/bin/bash
```

The following program searches the system password file and prints the entries for users who have no password:

```
awk -F: '$2 == ""' /etc/passwd
```

4.5.5 Field-Splitting Summary

It is important to remember that when you assign a string constant as the value of `FS`, it undergoes normal `awk` string processing. For example, with Unix `awk` and `gawk`, the assignment '`FS = "\.."`' assigns the character string `".."` to `FS` (the backslash is stripped). This creates a regexp meaning "fields are separated by occurrences of any two characters." If instead you want fields to be separated by a literal period followed by any single character, use '`FS = "\\.."`'.

The following table summarizes how fields are split, based on the value of `FS` ('`==`' means "is equal to"):

`FS == " "`
: Fields are separated by runs of whitespace. Leading and trailing whitespace are ignored. This is the default.

`FS ==` *`any other single character`*
: Fields are separated by each occurrence of the character. Multiple successive occurrences delimit empty fields, as do leading and trailing occurrences. The character can even be a regexp metacharacter; it does not need to be escaped.

`FS ==` *`regexp`*
: Fields are separated by occurrences of characters that match *regexp*. Leading and trailing matches of *regexp* delimit empty fields.

`FS == ""`
: Each individual character in the record becomes a separate field. (This is a `gawk` extension; it is not specified by the POSIX standard.)

Changing FS Does Not Affect the Fields

According to the POSIX standard, awk is supposed to behave as if each record is split into fields at the time it is read. In particular, this means that if you change the value of FS after a record is read, the value of the fields (i.e., how they were split) should reflect the old value of FS, not the new one.

However, many older implementations of awk do not work this way. Instead, they defer splitting the fields until a field is actually referenced. The fields are split using the *current* value of FS! This behavior can be difficult to diagnose. The following example illustrates the difference between the two methods. (The sed[3] command prints just the first line of /etc/passwd.)

```
sed 1q /etc/passwd | awk '{ FS = ":" ; print $1 }'
```

which usually prints:

```
root
```

on an incorrect implementation of awk, while gawk prints something like:

```
root:nSijPlPhZZwgE:0:0:Root:/:
```

FS and IGNORECASE

The IGNORECASE variable (see Section 7.5.1 [Built-in Variables That Control awk], page 135) affects field splitting *only* when the value of FS is a regexp. It has no effect when FS is a single character, even if that character is a letter. Thus, in the following code:

```
FS = "c"
IGNORECASE = 1
$0 = "aCa"
print $1
```

The output is 'aCa'. If you really want to split fields on an alphabetic character while ignoring case, use a regexp that will do it for you. E.g., 'FS = "[c]"'. In this case, IGNORECASE will take effect.

4.6 Reading Fixed-Width Data

> **NOTE:** This section discusses an advanced feature of gawk. If you are a novice awk user, you might want to skip it on the first reading.

gawk provides a facility for dealing with fixed-width fields with no distinctive field separator. For example, data of this nature arises in the input for old Fortran programs where numbers are run together, or in the output of programs that did not anticipate the use of their output as input for other programs.

An example of the latter is a table where all the columns are lined up by the use of a variable number of spaces and *empty fields are just spaces*. Clearly, awk's normal field splitting based on FS does not work well in this case. Although a portable awk program can use a series of substr() calls on $0 (see Section 9.1.3 [String-Manipulation Functions], page 161), this is awkward and inefficient for a large number of fields.

[3] The sed utility is a "stream editor." Its behavior is also defined by the POSIX standard.

The splitting of an input record into fixed-width fields is specified by assigning a string containing space-separated numbers to the built-in variable `FIELDWIDTHS`. Each number specifies the width of the field, *including* columns between fields. If you want to ignore the columns between fields, you can specify the width as a separate field that is subsequently ignored. It is a fatal error to supply a field width that is not a positive number. The following data is the output of the Unix `w` utility. It is useful to illustrate the use of `FIELDWIDTHS`:

```
 10:06pm  up 21 days, 14:04,  23 users
User     tty       login  idle   JCPU   PCPU  what
hzuo     ttyV0     8:58pm            9      5  vi p24.tex
hzang    ttyV3     6:37pm    50                -csh
eklye    ttyV5     9:53pm            7      1  em thes.tex
dportein ttyV6     8:17pm  1:47                -csh
gierd    ttyD3    10:00pm     1                elm
dave     ttyD4     9:47pm            4      4  w
brent    ttyp0    26Jun91  4:46  26:46   4:41  bash
dave     ttyq4    26Jun9115days     46     46  wnewmail
```

The following program takes the above input, converts the idle time to number of seconds, and prints out the first two fields and the calculated idle time:

> **NOTE:** This program uses a number of `awk` features that haven't been introduced yet.

```
BEGIN  { FIELDWIDTHS = "9 6 10 6 7 7 35" }
NR > 2 {
    idle = $4
    sub(/^  */, "", idle)   # strip leading spaces
    if (idle == "")
        idle = 0
    if (idle ~ /:/) {
        split(idle, t, ":")
        idle = t[1] * 60 + t[2]
    }
    if (idle ~ /days/)
        idle *= 24 * 60 * 60

    print $1, $2, idle
}
```

Running the program on the data produces the following results:

```
hzuo      ttyV0  0
hzang     ttyV3  50
eklye     ttyV5  0
dportein  ttyV6  107
gierd     ttyD3  1
dave      ttyD4  0
brent     ttyp0  286
dave      ttyq4  1296000
```

Another (possibly more practical) example of fixed-width input data is the input from a deck of balloting cards. In some parts of the United States, voters mark their choices by punching holes in computer cards. These cards are then processed to count the votes for any particular candidate or on any particular issue. Because a voter may choose not to vote on some issue, any column on the card may be empty. An `awk` program for processing such data could use the `FIELDWIDTHS` feature to simplify reading the data. (Of course, getting `gawk` to run on a system with card readers is another story!)

Assigning a value to `FS` causes `gawk` to use `FS` for field splitting again. Use '`FS = FS`' to make this happen, without having to know the current value of `FS`. In order to tell which kind of field splitting is in effect, use `PROCINFO["FS"]` (see Section 7.5.2 [Built-in Variables That Convey Information], page 137). The value is `"FS"` if regular field splitting is being used, or it is `"FIELDWIDTHS"` if fixed-width field splitting is being used:

```
if (PROCINFO["FS"] == "FS")
    regular field splitting ...
else if  (PROCINFO["FS"] == "FIELDWIDTHS")
    fixed-width field splitting ...
else
    content-based field splitting ... (see next section)
```

This information is useful when writing a function that needs to temporarily change `FS` or `FIELDWIDTHS`, read some records, and then restore the original settings (see Section 10.5 [Reading the User Database], page 221, for an example of such a function).

4.7 Defining Fields By Content

> **NOTE:** This section discusses an advanced feature of `gawk`. If you are a novice `awk` user, you might want to skip it on the first reading.

Normally, when using `FS`, `gawk` defines the fields as the parts of the record that occur in between each field separator. In other words, `FS` defines what a field *is not*, instead of what a field *is*. However, there are times when you really want to define the fields by what they are, and not by what they are not.

The most notorious such case is so-called *comma separated value* (CSV) data. Many spreadsheet programs, for example, can export their data into text files, where each record is terminated with a newline, and fields are separated by commas. If only commas separated the data, there wouldn't be an issue. The problem comes when one of the fields contains an *embedded* comma. While there is no formal standard specification for CSV data[4], in such cases, most programs embed the field in double quotes. So we might have data like this:

```
Robbins,Arnold,"1234 A Pretty Street, NE",MyTown,MyState,12345-6789,USA
```

The `FPAT` variable offers a solution for cases like this. The value of `FPAT` should be a string that provides a regular expression. This regular expression describes the contents of each field.

In the case of CSV data as presented above, each field is either "anything that is not a comma," or "a double quote, anything that is not a double quote, and a closing double quote." If written as a regular expression constant (see Chapter 3 [Regular Expressions],

[4] At least, we don't know of one.

page 43), we would have `/([^,]+)|("[^"]+")/`. Writing this as a string requires us to escape the double quotes, leading to:

```
FPAT = "([^,]+)|(\"[^\"]+\")"
```

Putting this to use, here is a simple program to parse the data:

```
BEGIN {
    FPAT = "([^,]+)|(\"[^\"]+\")"
}

{
    print "NF = ", NF
    for (i = 1; i <= NF; i++) {
        printf("$%d = <%s>\n", i, $i)
    }
}
```

When run, we get the following:

```
$ gawk -f simple-csv.awk addresses.csv
NF =  7
$1 = <Robbins>
$2 = <Arnold>
$3 = <"1234 A Pretty Street, NE">
$4 = <MyTown>
$5 = <MyState>
$6 = <12345-6789>
$7 = <USA>
```

Note the embedded comma in the value of `$3`.

A straightforward improvement when processing CSV data of this sort would be to remove the quotes when they occur, with something like this:

```
if (substr($i, 1, 1) == "\"") {
    len = length($i)
    $i = substr($i, 2, len - 2)    # Get text within the two quotes
}
```

As with `FS`, the `IGNORECASE` variable (see Section 7.5.1 [Built-in Variables That Control `awk`], page 135) affects field splitting with `FPAT`.

Similar to `FIELDWIDTHS`, the value of `PROCINFO["FS"]` will be `"FPAT"` if content-based field splitting is being used.

> **NOTE:** Some programs export CSV data that contains embedded newlines between the double quotes. `gawk` provides no way to deal with this. Since there is no formal specification for CSV data, there isn't much more to be done; the `FPAT` mechanism provides an elegant solution for the majority of cases, and the `gawk` maintainer is satisfied with that.

As written, the regexp used for `FPAT` requires that each field have a least one character. A straightforward modification (changing changed the first '`+`' to '`*`') allows fields to be empty:

```
FPAT = "([^,]*)|(\"[^\"]+\")"
```

Finally, the `patsplit()` function makes the same functionality available for splitting regular strings (see Section 9.1.3 [String-Manipulation Functions], page 161).

4.8 Multiple-Line Records

In some databases, a single line cannot conveniently hold all the information in one entry. In such cases, you can use multiline records. The first step in doing this is to choose your data format.

One technique is to use an unusual character or string to separate records. For example, you could use the formfeed character (written '`\f`' in `awk`, as in C) to separate them, making each record a page of the file. To do this, just set the variable `RS` to `"\f"` (a string containing the formfeed character). Any other character could equally well be used, as long as it won't be part of the data in a record.

Another technique is to have blank lines separate records. By a special dispensation, an empty string as the value of `RS` indicates that records are separated by one or more blank lines. When `RS` is set to the empty string, each record always ends at the first blank line encountered. The next record doesn't start until the first nonblank line that follows. No matter how many blank lines appear in a row, they all act as one record separator. (Blank lines must be completely empty; lines that contain only whitespace do not count.)

You can achieve the same effect as '`RS = ""`' by assigning the string `"\n\n+"` to `RS`. This regexp matches the newline at the end of the record and one or more blank lines after the record. In addition, a regular expression always matches the longest possible sequence when there is a choice (see Section 3.7 [How Much Text Matches?], page 52). So the next record doesn't start until the first nonblank line that follows—no matter how many blank lines appear in a row, they are considered one record separator.

There is an important difference between '`RS = ""`' and '`RS = "\n\n+"`'. In the first case, leading newlines in the input data file are ignored, and if a file ends without extra blank lines after the last record, the final newline is removed from the record. In the second case, this special processing is not done.

Now that the input is separated into records, the second step is to separate the fields in the record. One way to do this is to divide each of the lines into fields in the normal manner. This happens by default as the result of a special feature. When `RS` is set to the empty string, *and* `FS` is set to a single character, the newline character *always* acts as a field separator. This is in addition to whatever field separations result from `FS`.[5]

The original motivation for this special exception was probably to provide useful behavior in the default case (i.e., `FS` is equal to `" "`). This feature can be a problem if you really don't want the newline character to separate fields, because there is no way to prevent it. However, you can work around this by using the `split()` function to break up the record manually (see Section 9.1.3 [String-Manipulation Functions], page 161). If you have a single character field separator, you can work around the special feature in a different way, by making `FS` into a regexp for that single character. For example, if the field separator is a percent character, instead of '`FS = "%"`', use '`FS = "[%]"`'.

---

[5] When `FS` is the null string (`""`) or a regexp, this special feature of `RS` does not apply. It does apply to the default field separator of a single space: '`FS = " "`'.

Another way to separate fields is to put each field on a separate line: to do this, just set the variable FS to the string "\n". (This single character separator matches a single newline.) A practical example of a data file organized this way might be a mailing list, where each entry is separated by blank lines. Consider a mailing list in a file named addresses, which looks like this:

```
Jane Doe
123 Main Street
Anywhere, SE 12345-6789

John Smith
456 Tree-lined Avenue
Smallville, MW 98765-4321
...
```

A simple program to process this file is as follows:

```
# addrs.awk --- simple mailing list program

# Records are separated by blank lines.
# Each line is one field.
BEGIN { RS = "" ; FS = "\n" }

{
      print "Name is:", $1
      print "Address is:", $2
      print "City and State are:", $3
      print ""
}
```

Running the program produces the following output:

```
$ awk -f addrs.awk addresses
⊣ Name is: Jane Doe
⊣ Address is: 123 Main Street
⊣ City and State are: Anywhere, SE 12345-6789
⊣
⊣ Name is: John Smith
⊣ Address is: 456 Tree-lined Avenue
⊣ City and State are: Smallville, MW 98765-4321
⊣
...
```

See Section 11.3.4 [Printing Mailing Labels], page 257, for a more realistic program that deals with address lists. The following table summarizes how records are split, based on the value of RS:

RS == "\n"
: Records are separated by the newline character ('\n'). In effect, every line in the data file is a separate record, including blank lines. This is the default.

`RS == any single character`
: Records are separated by each occurrence of the character. Multiple successive occurrences delimit empty records.

`RS == ""`
: Records are separated by runs of blank lines. When `FS` is a single character, then the newline character always serves as a field separator, in addition to whatever value `FS` may have. Leading and trailing newlines in a file are ignored.

`RS == regexp`
: Records are separated by occurrences of characters that match *regexp*. Leading and trailing matches of *regexp* delimit empty records. (This is a `gawk` extension; it is not specified by the POSIX standard.)

In all cases, `gawk` sets `RT` to the input text that matched the value specified by `RS`. But if the input file ended without any text that matches `RS`, then `gawk` sets `RT` to the null string.

4.9 Explicit Input with `getline`

So far we have been getting our input data from `awk`'s main input stream—either the standard input (usually your terminal, sometimes the output from another program) or from the files specified on the command line. The `awk` language has a special built-in command called `getline` that can be used to read input under your explicit control.

The `getline` command is used in several different ways and should *not* be used by beginners. The examples that follow the explanation of the `getline` command include material that has not been covered yet. Therefore, come back and study the `getline` command *after* you have reviewed the rest of this book and have a good knowledge of how `awk` works.

The `getline` command returns one if it finds a record and zero if it encounters the end of the file. If there is some error in getting a record, such as a file that cannot be opened, then `getline` returns −1. In this case, `gawk` sets the variable `ERRNO` to a string describing the error that occurred.

In the following examples, *command* stands for a string value that represents a shell command.

> **NOTE:** When `--sandbox` is specified (see Section 2.2 [Command-Line Options], page 29), reading lines from files, pipes and coprocesses is disabled.

4.9.1 Using `getline` with No Arguments

The `getline` command can be used without arguments to read input from the current input file. All it does in this case is read the next input record and split it up into fields. This is useful if you've finished processing the current record, but want to do some special processing on the next record *right now*. For example:

```
{
     if ((t = index($0, "/*")) != 0) {
          # value of ‘tmp’ will be "" if t is 1
          tmp = substr($0, 1, t - 1)
          u = index(substr($0, t + 2), "*/")
          offset = t + 2
          while (u == 0) {
```

```
                if (getline <= 0) {
                    m = "unexpected EOF or error"
                    m = (m ": " ERRNO)
                    print m > "/dev/stderr"
                    exit
                }
                u = index($0, "*/")
                offset = 0
            }
            # substr() expression will be "" if */
            # occurred at end of line
            $0 = tmp substr($0, offset + u + 2)
        }
        print $0
    }
```

This `awk` program deletes C-style comments ('`/* ... */`') from the input. By replacing the '`print $0`' with other statements, you could perform more complicated processing on the decommented input, such as searching for matches of a regular expression. (This program has a subtle problem—it does not work if one comment ends and another begins on the same line.)

This form of the `getline` command sets `NF`, `NR`, `FNR`, `RT`, and the value of `$0`.

> **NOTE:** The new value of `$0` is used to test the patterns of any subsequent rules. The original value of `$0` that triggered the rule that executed `getline` is lost. By contrast, the `next` statement reads a new record but immediately begins processing it normally, starting with the first rule in the program. See Section 7.4.8 [The `next` Statement], page 132.

4.9.2 Using `getline` into a Variable

You can use '`getline` *var*' to read the next record from `awk`'s input into the variable *var*. No other processing is done. For example, suppose the next line is a comment or a special string, and you want to read it without triggering any rules. This form of `getline` allows you to read that line and store it in a variable so that the main read-a-line-and-check-each-rule loop of `awk` never sees it. The following example swaps every two lines of input:

```
{
    if ((getline tmp) > 0) {
        print tmp
        print $0
    } else
        print $0
}
```

It takes the following list:

```
wan
tew
free
phore
```

and produces these results:

```
tew
wan
phore
free
```

The getline command used in this way sets only the variables NR, FNR and RT (and of course, *var*). The record is not split into fields, so the values of the fields (including $0) and the value of NF do not change.

4.9.3 Using getline from a File

Use '`getline < file`' to read the next record from *file*. Here *file* is a string-valued expression that specifies the file name. '`< file`' is called a *redirection* because it directs input to come from a different place. For example, the following program reads its input record from the file secondary.input when it encounters a first field with a value equal to 10 in the current input file:

```
{
    if ($1 == 10) {
         getline < "secondary.input"
         print
    } else
         print
}
```

Because the main input stream is not used, the values of NR and FNR are not changed. However, the record it reads is split into fields in the normal manner, so the values of $0 and the other fields are changed, resulting in a new value of NF. RT is also set.

According to POSIX, '`getline < expression`' is ambiguous if *expression* contains unparenthesized operators other than '$'; for example, '`getline < dir "/" file`' is ambiguous because the concatenation operator is not parenthesized. You should write it as '`getline < (dir "/" file)`' if you want your program to be portable to all awk implementations.

4.9.4 Using getline into a Variable from a File

Use '`getline var < file`' to read input from the file *file*, and put it in the variable *var*. As above, *file* is a string-valued expression that specifies the file from which to read.

In this version of getline, none of the built-in variables are changed and the record is not split into fields. The only variable changed is *var*.[6] For example, the following program copies all the input files to the output, except for records that say '`@include filename`'. Such a record is replaced by the contents of the file *filename*:

```
{
     if (NF == 2 && $1 == "@include") {
          while ((getline line < $2) > 0)
               print line
          close($2)
     } else
```

[6] This is not quite true. RT could be changed if RS is a regular expression.

```
            print
    }
```

Note here how the name of the extra input file is not built into the program; it is taken directly from the data, specifically from the second field on the '@include' line.

The close() function is called to ensure that if two identical '@include' lines appear in the input, the entire specified file is included twice. See Section 5.8 [Closing Input and Output Redirections], page 94.

One deficiency of this program is that it does not process nested '@include' statements (i.e., '@include' statements in included files) the way a true macro preprocessor would. See Section 11.3.9 [An Easy Way to Use Library Functions], page 266, for a program that does handle nested '@include' statements.

4.9.5 Using getline from a Pipe

Omniscience has much to recommend it. Failing that, attention to details would be useful.
Brian Kernighan

The output of a command can also be piped into getline, using '*command* | getline'. In this case, the string *command* is run as a shell command and its output is piped into awk to be used as input. This form of getline reads one record at a time from the pipe. For example, the following program copies its input to its output, except for lines that begin with '@execute', which are replaced by the output produced by running the rest of the line as a shell command:

```
{
     if ($1 == "@execute") {
          tmp = substr($0, 10)        # Remove "@execute"
          while ((tmp | getline) > 0)
               print
          close(tmp)
     } else
          print
}
```

The close() function is called to ensure that if two identical '@execute' lines appear in the input, the command is run for each one. Given the input:

```
foo
bar
baz
@execute who
bletch
```

the program might produce:

```
foo
bar
baz
arnold     ttyv0   Jul 13 14:22
miriam     ttyp0   Jul 13 14:23     (murphy:0)
bill       ttyp1   Jul 13 14:23     (murphy:0)
```

```
bletch
```

Notice that this program ran the command `who` and printed the previous result. (If you try this program yourself, you will of course get different results, depending upon who is logged in on your system.)

This variation of `getline` splits the record into fields, sets the value of `NF`, and recomputes the value of `$0`. The values of `NR` and `FNR` are not changed. `RT` is set.

According to POSIX, '*`expression`* `| getline`' is ambiguous if *expression* contains unparenthesized operators other than '`$`'—for example, '`"echo " "date" | getline`' is ambiguous because the concatenation operator is not parenthesized. You should write it as '`("echo " "date") | getline`' if you want your program to be portable to all `awk` implementations.

> **NOTE:** Unfortunately, `gawk` has not been consistent in its treatment of a construct like '`"echo " "date" | getline`'. Most versions, including the current version, treat it at as '`("echo " "date") | getline`'. (This how Brian Kernighan's `awk` behaves.) Some versions changed and treated it as '`"echo " ("date" | getline)`'. (This is how `mawk` behaves.) In short, *always* use explicit parentheses, and then you won't have to worry.

4.9.6 Using `getline` into a Variable from a Pipe

When you use '*`command`* `| getline` *`var`*', the output of *command* is sent through a pipe to `getline` and into the variable *var*. For example, the following program reads the current date and time into the variable `current_time`, using the `date` utility, and then prints it:

```
BEGIN {
     "date" | getline current_time
     close("date")
     print "Report printed on " current_time
}
```

In this version of `getline`, none of the built-in variables are changed and the record is not split into fields.

4.9.7 Using `getline` from a Coprocess

Input into `getline` from a pipe is a one-way operation. The command that is started with '*`command`* `| getline`' only sends data *to* your `awk` program.

On occasion, you might want to send data to another program for processing and then read the results back. `gawk` allows you to start a *coprocess*, with which two-way communications are possible. This is done with the '`|&`' operator. Typically, you write data to the coprocess first and then read results back, as shown in the following:

```
print "some query" |& "db_server"
"db_server" |& getline
```

which sends a query to `db_server` and then reads the results.

The values of `NR` and `FNR` are not changed, because the main input stream is not used. However, the record is split into fields in the normal manner, thus changing the values of `$0`, of the other fields, and of `NF` and `RT`.

Coprocesses are an advanced feature. They are discussed here only because this is the section on `getline`. See Section 12.3 [Two-Way Communications with Another Process], page 283, where coprocesses are discussed in more detail.

4.9.8 Using `getline` into a Variable from a Coprocess

When you use '*`command`* `|& getline` *`var`*', the output from the coprocess *command* is sent through a two-way pipe to `getline` and into the variable *var*.

In this version of `getline`, none of the built-in variables are changed and the record is not split into fields. The only variable changed is *var*. However, `RT` is set.

4.9.9 Points to Remember About `getline`

Here are some miscellaneous points about `getline` that you should bear in mind:

- When `getline` changes the value of `$0` and `NF`, `awk` does *not* automatically jump to the start of the program and start testing the new record against every pattern. However, the new record is tested against any subsequent rules.
- Many `awk` implementations limit the number of pipelines that an `awk` program may have open to just one. In `gawk`, there is no such limit. You can open as many pipelines (and coprocesses) as the underlying operating system permits.
- An interesting side effect occurs if you use `getline` without a redirection inside a `BEGIN` rule. Because an unredirected `getline` reads from the command-line data files, the first `getline` command causes `awk` to set the value of `FILENAME`. Normally, `FILENAME` does not have a value inside `BEGIN` rules, because you have not yet started to process the command-line data files. (See Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122, also see Section 7.5.2 [Built-in Variables That Convey Information], page 137.)
- Using `FILENAME` with `getline` ('`getline < FILENAME`') is likely to be a source for confusion. `awk` opens a separate input stream from the current input file. However, by not using a variable, `$0` and `NR` are still updated. If you're doing this, it's probably by accident, and you should reconsider what it is you're trying to accomplish.
- Section 4.9.10 [Summary of `getline` Variants], page 79, presents a table summarizing the `getline` variants and which variables they can affect. It is worth noting that those variants which do not use redirection can cause `FILENAME` to be updated if they cause `awk` to start reading a new input file.
- If the variable being assigned is an expression with side effects, different versions of `awk` behave differently upon encountering end-of-file. Some versions don't evaluate the expression; many versions (including `gawk`) do. Here is an example, due to Duncan Moore:

  ```
  BEGIN {
      system("echo 1 > f")
      while ((getline a[++c] < "f") > 0) { }
      print c
  }
  ```

  Here, the side effect is the '`++c`'. Is `c` incremented if end of file is encountered, before the element in `a` is assigned?

gawk treats getline like a function call, and evaluates the expression 'a[++c]' before attempting to read from f. Other versions of awk only evaluate the expression once they know that there is a string value to be assigned. Caveat Emptor.

4.9.10 Summary of getline Variants

Table 4.1 summarizes the eight variants of getline, listing which built-in variables are set by each one, and whether the variant is standard or a gawk extension. Note: for each variant, gawk sets the RT built-in variable.

Variant	**Effect**	**Standard / Extension**
getline	Sets $0, NF, FNR, NR, and RT	Standard
getline *var*	Sets *var*, FNR, NR, and RT	Standard
getline < *file*	Sets $0, NF, and RT	Standard
getline *var* < *file*	Sets *var* and RT	Standard
command | getline	Sets $0, NF, and RT	Standard
command | getline *var*	Sets *var* and RT	Standard
command |& getline	Sets $0, NF, and RT	Extension
command |& getline *var*	Sets *var* and RT	Extension

Table 4.1: getline Variants and What They Set

4.10 Reading Input With A Timeout

You may specify a timeout in milliseconds for reading input from a terminal, pipe or two-way communication including, TCP/IP sockets. This can be done on a per input, command or connection basis, by setting a special element in the PROCINFO array:

```
PROCINFO["input_name", "READ_TIMEOUT"] = timeout in milliseconds
```

When set, this causes gawk to time out and return failure if no data is available to read within the specified timeout period. For example, a TCP client can decide to give up on receiving any response from the server after a certain amount of time:

```
Service = "/inet/tcp/0/localhost/daytime"
PROCINFO[Service, "READ_TIMEOUT"] = 100
if ((Service |& getline) > 0)
    print $0
else if (ERRNO != "")
    print ERRNO
```

Here is how to read interactively from the terminal[7] without waiting for more than five seconds:

```
PROCINFO["/dev/stdin", "READ_TIMEOUT"] = 5000
while ((getline < "/dev/stdin") > 0)
    print $0
```

gawk will terminate the read operation if input does not arrive after waiting for the timeout period, return failure and set the ERRNO variable to an appropriate string value. A negative or zero value for the timeout is the same as specifying no timeout at all.

[7] This assumes that standard input is the keyboard

A timeout can also be set for reading from the terminal in the implicit loop that reads input records and matches them against patterns, like so:

```
$ gawk 'BEGIN { PROCINFO["-", "READ_TIMEOUT"] = 5000 }
> { print "You entered: " $0 }'
gawk
⊣ You entered: gawk
```

In this case, failure to respond within five seconds results in the following error message:

```
error gawk: cmd. line:2: (FILENAME=- FNR=1) fatal: error reading input file '-
': Connection timed out
```

The timeout can be set or changed at any time, and will take effect on the next attempt to read from the input device. In the following example, we start with a timeout value of one second, and progressively reduce it by one-tenth of a second until we wait indefinitely for the input to arrive:

```
PROCINFO[Service, "READ_TIMEOUT"] = 1000
while ((Service |& getline) > 0) {
    print $0
    PROCINFO[S, "READ_TIMEOUT"] -= 100
}
```

> **NOTE:** You should not assume that the read operation will block exactly after the tenth record has been printed. It is possible that `gawk` will read and buffer more than one record's worth of data the first time. Because of this, changing the value of timeout like in the above example is not very useful.

If the `PROCINFO` element is not present and the environment variable `GAWK_READ_TIMEOUT` exists, `gawk` uses its value to initialize the timeout value. The exclusive use of the environment variable to specify timeout has the disadvantage of not being able to control it on a per command or connection basis.

`gawk` considers a timeout event to be an error even though the attempt to read from the underlying device may succeed in a later attempt. This is a limitation, and it also means that you cannot use this to multiplex input from two or more sources.

Assigning a timeout value prevents read operations from blocking indefinitely. But bear in mind that there are other ways `gawk` can stall waiting for an input device to be ready. A network client can sometimes take a long time to establish a connection before it can start reading any data, or the attempt to open a FIFO special file for reading can block indefinitely until some other process opens it for writing.

4.11 Directories On The Command Line

According to the POSIX standard, files named on the `awk` command line must be text files. It is a fatal error if they are not. Most versions of `awk` treat a directory on the command line as a fatal error.

By default, `gawk` produces a warning for a directory on the command line, but otherwise ignores it. If either of the `--posix` or `--traditional` options is given, then `gawk` reverts to treating a directory on the command line as a fatal error.

5 Printing Output

One of the most common programming actions is to *print*, or output, some or all of the input. Use the `print` statement for simple output, and the `printf` statement for fancier formatting. The `print` statement is not limited when computing *which* values to print. However, with two exceptions, you cannot specify *how* to print them—how many columns, whether to use exponential notation or not, and so on. (For the exceptions, see Section 5.3 [Output Separators], page 83, and Section 5.4 [Controlling Numeric Output with `print`], page 83.) For printing with specifications, you need the `printf` statement (see Section 5.5 [Using `printf` Statements for Fancier Printing], page 84).

Besides basic and formatted printing, this chapter also covers I/O redirections to files and pipes, introduces the special file names that `gawk` processes internally, and discusses the `close()` built-in function.

5.1 The `print` Statement

The `print` statement is used for producing output with simple, standardized formatting. Specify only the strings or numbers to print, in a list separated by commas. They are output, separated by single spaces, followed by a newline. The statement looks like this:

```
print item1, item2, ...
```

The entire list of items may be optionally enclosed in parentheses. The parentheses are necessary if any of the item expressions uses the '`>`' relational operator; otherwise it could be confused with an output redirection (see Section 5.6 [Redirecting Output of `print` and `printf`], page 89).

The items to print can be constant strings or numbers, fields of the current record (such as `$1`), variables, or any `awk` expression. Numeric values are converted to strings and then printed.

The simple statement '`print`' with no items is equivalent to '`print $0`': it prints the entire current record. To print a blank line, use '`print ""`', where `""` is the empty string. To print a fixed piece of text, use a string constant, such as `"Don't Panic"`, as one item. If you forget to use the double-quote characters, your text is taken as an `awk` expression, and you will probably get an error. Keep in mind that a space is printed between any two items.

5.2 `print` Statement Examples

Each `print` statement makes at least one line of output. However, it isn't limited to only one line. If an item value is a string containing a newline, the newline is output along with the rest of the string. A single `print` statement can make any number of lines this way.

The following is an example of printing a string that contains embedded newlines (the '`\n`' is an escape sequence, used to represent the newline character; see Section 3.2 [Escape Sequences], page 44):

```
$ awk 'BEGIN { print "line one\nline two\nline three" }'
⊣ line one
⊣ line two
⊣ line three
```

The next example, which is run on the `inventory-shipped` file, prints the first two fields of each input record, with a space between them:

```
$ awk '{ print $1, $2 }' inventory-shipped
⊣ Jan 13
⊣ Feb 15
⊣ Mar 15
...
```

A common mistake in using the `print` statement is to omit the comma between two items. This often has the effect of making the items run together in the output, with no space. The reason for this is that juxtaposing two string expressions in `awk` means to concatenate them. Here is the same program, without the comma:

```
$ awk '{ print $1 $2 }' inventory-shipped
⊣ Jan13
⊣ Feb15
⊣ Mar15
...
```

To someone unfamiliar with the `inventory-shipped` file, neither example's output makes much sense. A heading line at the beginning would make it clearer. Let's add some headings to our table of months (`$1`) and green crates shipped (`$2`). We do this using the `BEGIN` pattern (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122) so that the headings are only printed once:

```
awk 'BEGIN {  print "Month Crates"
              print "----- ------" }
           {  print $1, $2 }' inventory-shipped
```

When run, the program prints the following:

```
Month Crates
----- ------
Jan 13
Feb 15
Mar 15
...
```

The only problem, however, is that the headings and the table data don't line up! We can fix this by printing some spaces between the two fields:

```
awk 'BEGIN { print "Month Crates"
             print "----- ------" }
           { print $1, "     ", $2 }' inventory-shipped
```

Lining up columns this way can get pretty complicated when there are many columns to fix. Counting spaces for two or three columns is simple, but any more than this can take up a lot of time. This is why the `printf` statement was created (see Section 5.5 [Using `printf` Statements for Fancier Printing], page 84); one of its specialties is lining up columns of data.

> **NOTE:** You can continue either a `print` or `printf` statement simply by putting a newline after any comma (see Section 1.6 [`awk` Statements Versus Lines], page 25).

5.3 Output Separators

As mentioned previously, a `print` statement contains a list of items separated by commas. In the output, the items are normally separated by single spaces. However, this doesn't need to be the case; a single space is simply the default. Any string of characters may be used as the *output field separator* by setting the built-in variable `OFS`. The initial value of this variable is the string `" "`—that is, a single space.

The output from an entire `print` statement is called an *output record*. Each `print` statement outputs one output record, and then outputs a string called the *output record separator* (or `ORS`). The initial value of `ORS` is the string `"\n"`; i.e., a newline character. Thus, each `print` statement normally makes a separate line.

In order to change how output fields and records are separated, assign new values to the variables `OFS` and `ORS`. The usual place to do this is in the `BEGIN` rule (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122), so that it happens before any input is processed. It can also be done with assignments on the command line, before the names of the input files, or using the `-v` command-line option (see Section 2.2 [Command-Line Options], page 29). The following example prints the first and second fields of each input record, separated by a semicolon, with a blank line added after each newline:

```
$ awk 'BEGIN { OFS = ";"; ORS = "\n\n" }
>             { print $1, $2 }' BBS-list
⊣ aardvark;555-5553
⊣
⊣ alpo-net;555-3412
⊣
⊣ barfly;555-7685
...
```

If the value of `ORS` does not contain a newline, the program's output runs together on a single line.

5.4 Controlling Numeric Output with `print`

When printing numeric values with the `print` statement, `awk` internally converts the number to a string of characters and prints that string. `awk` uses the `sprintf()` function to do this conversion (see Section 9.1.3 [String-Manipulation Functions], page 161). For now, it suffices to say that the `sprintf()` function accepts a *format specification* that tells it how to format numbers (or strings), and that there are a number of different ways in which numbers can be formatted. The different format specifications are discussed more fully in Section 5.5.2 [Format-Control Letters], page 84.

The built-in variable `OFMT` contains the default format specification that `print` uses with `sprintf()` when it wants to convert a number to a string for printing. The default value of `OFMT` is `"%.6g"`. The way `print` prints numbers can be changed by supplying different format specifications as the value of `OFMT`, as shown in the following example:

```
$ awk 'BEGIN {
>   OFMT = "%.0f"  # print numbers as integers (rounds)
>   print 17.23, 17.54 }'
⊣ 17 18
```

According to the POSIX standard, awk's behavior is undefined if OFMT contains anything but a floating-point conversion specification.

5.5 Using printf Statements for Fancier Printing

For more precise control over the output format than what is provided by print, use printf. With printf you can specify the width to use for each item, as well as various formatting choices for numbers (such as what output base to use, whether to print an exponent, whether to print a sign, and how many digits to print after the decimal point). You do this by supplying a string, called the *format string*, that controls how and where to print the other arguments.

5.5.1 Introduction to the printf Statement

A simple printf statement looks like this:

```
printf format, item1, item2, ...
```

The entire list of arguments may optionally be enclosed in parentheses. The parentheses are necessary if any of the item expressions use the '>' relational operator; otherwise, it can be confused with an output redirection (see Section 5.6 [Redirecting Output of print and printf], page 89).

The difference between printf and print is the *format* argument. This is an expression whose value is taken as a string; it specifies how to output each of the other arguments. It is called the *format string*.

The format string is very similar to that in the ISO C library function printf(). Most of *format* is text to output verbatim. Scattered among this text are *format specifiers*—one per item. Each format specifier says to output the next item in the argument list at that place in the format.

The printf statement does not automatically append a newline to its output. It outputs only what the format string specifies. So if a newline is needed, you must include one in the format string. The output separator variables OFS and ORS have no effect on printf statements. For example:

```
$ awk 'BEGIN {
>     ORS = "\nOUCH!\n"; OFS = "+"
>     msg = "Dont Panic!"
>     printf "%s\n", msg
> }'
⊣ Dont Panic!
```

Here, neither the '+' nor the 'OUCH' appear in the output message.

5.5.2 Format-Control Letters

A format specifier starts with the character '%' and ends with a *format-control letter*—it tells the printf statement how to output one item. The format-control letter specifies what *kind* of value to print. The rest of the format specifier is made up of optional *modifiers* that control *how* to print the value, such as the field width. Here is a list of the format-control letters:

`%c` Print a number as an ASCII character; thus, '`printf "%c", 65`' outputs the letter '`A`'. The output for a string value is the first character of the string.

> **NOTE:** The POSIX standard says the first character of a string is printed. In locales with multibyte characters, `gawk` attempts to convert the leading bytes of the string into a valid wide character and then to print the multibyte encoding of that character. Similarly, when printing a numeric value, `gawk` allows the value to be within the numeric range of values that can be held in a wide character.
>
> Other `awk` versions generally restrict themselves to printing the first byte of a string or to numeric values within the range of a single byte (0–255).

`%d`, `%i` Print a decimal integer. The two control letters are equivalent. (The '`%i`' specification is for compatibility with ISO C.)

`%e`, `%E` Print a number in scientific (exponential) notation; for example:

```
printf "%4.3e\n", 1950
```

prints '`1.950e+03`', with a total of four significant figures, three of which follow the decimal point. (The '`4.3`' represents two modifiers, discussed in the next subsection.) '`%E`' uses '`E`' instead of '`e`' in the output.

`%f` Print a number in floating-point notation. For example:

```
printf "%4.3f", 1950
```

prints '`1950.000`', with a total of four significant figures, three of which follow the decimal point. (The '`4.3`' represents two modifiers, discussed in the next subsection.)

On systems supporting IEEE 754 floating point format, values representing negative infinity are formatted as '`-inf`' or '`-infinity`', and positive infinity as '`inf`' and '`infinity`'. The special "not a number" value formats as '`-nan`' or '`nan`'.

`%F` Like '`%f`' but the infinity and "not a number" values are spelled using uppercase letters.

The '`%F`' format is a POSIX extension to ISO C; not all systems support it. On those that don't, `gawk` uses '`%f`' instead.

`%g`, `%G` Print a number in either scientific notation or in floating-point notation, whichever uses fewer characters; if the result is printed in scientific notation, '`%G`' uses '`E`' instead of '`e`'.

`%o` Print an unsigned octal integer (see Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97).

`%s` Print a string.

`%u` Print an unsigned decimal integer. (This format is of marginal use, because all numbers in `awk` are floating-point; it is provided primarily for compatibility with C.)

`%x`, `%X` Print an unsigned hexadecimal integer; '`%X`' uses the letters '`A`' through '`F`' instead of '`a`' through '`f`' (see Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97).

`%%` Print a single '`%`'. This does not consume an argument and it ignores any modifiers.

> **NOTE:** When using the integer format-control letters for values that are outside the range of the widest C integer type, `gawk` switches to the '`%g`' format specifier. If `--lint` is provided on the command line (see Section 2.2 [Command-Line Options], page 29), `gawk` warns about this. Other versions of `awk` may print invalid values or do something else entirely.

5.5.3 Modifiers for `printf` Formats

A format specification can also include *modifiers* that can control how much of the item's value is printed, as well as how much space it gets. The modifiers come between the '`%`' and the format-control letter. We will use the bullet symbol "•" in the following examples to represent spaces in the output. Here are the possible modifiers, in the order in which they may appear:

`N$` An integer constant followed by a '`$`' is a *positional specifier*. Normally, format specifications are applied to arguments in the order given in the format string. With a positional specifier, the format specification is applied to a specific argument, instead of what would be the next argument in the list. Positional specifiers begin counting with one. Thus:

```
printf "%s %s\n", "don't", "panic"
printf "%2$s %1$s\n", "panic", "don't"
```

prints the famous friendly message twice.

At first glance, this feature doesn't seem to be of much use. It is in fact a `gawk` extension, intended for use in translating messages at runtime. See Section 13.4.2 [Rearranging `printf` Arguments], page 295, which describes how and why to use positional specifiers. For now, we will not use them.

`-` The minus sign, used before the width modifier (see later on in this list), says to left-justify the argument within its specified width. Normally, the argument is printed right-justified in the specified width. Thus:

```
printf "%-4s", "foo"
```

prints '`foo•`'.

`space` For numeric conversions, prefix positive values with a space and negative values with a minus sign.

`+` The plus sign, used before the width modifier (see later on in this list), says to always supply a sign for numeric conversions, even if the data to format is positive. The '`+`' overrides the space modifier.

`#` Use an "alternate form" for certain control letters. For '`%o`', supply a leading zero. For '`%x`' and '`%X`', supply a leading '`0x`' or '`0X`' for a nonzero result. For '`%e`', '`%E`', '`%f`', and '`%F`', the result always contains a decimal point. For '`%g`' and '`%G`', trailing zeros are not removed from the result.

`0`
: A leading '`0`' (zero) acts as a flag that indicates that output should be padded with zeros instead of spaces. This applies only to the numeric output formats. This flag only has an effect when the field width is wider than the value to print.

`'`
: A single quote or apostrophe character is a POSIX extension to ISO C. It indicates that the integer part of a floating point value, or the entire part of an integer decimal value, should have a thousands-separator character in it. This only works in locales that support such characters. For example:

```
$ cat thousands.awk                Show source program
⊣ BEGIN { printf "%'d\n", 1234567 }
$ LC_ALL=C gawk -f thousands.awk
⊣ 1234567                          Results in "C" locale
$ LC_ALL=en_US.UTF-8 gawk -f thousands.awk
⊣ 1,234,567                        Results in US English UTF locale
```

For more information about locales and internationalization issues, see Section 6.6 [Where You Are Makes A Difference], page 118.

> **NOTE:** The '`'`' flag is a nice feature, but its use complicates things: it becomes difficult to use it in command-line programs. For information on appropriate quoting tricks, see Section 1.1.6 [Shell-Quoting Issues], page 19.

`width`
: This is a number specifying the desired minimum width of a field. Inserting any number between the '`%`' sign and the format-control character forces the field to expand to this width. The default way to do this is to pad with spaces on the left. For example:

```
printf "%4s", "foo"
```

prints '`•foo`'.

The value of *width* is a minimum width, not a maximum. If the item value requires more than *width* characters, it can be as wide as necessary. Thus, the following:

```
printf "%4s", "foobar"
```

prints '`foobar`'.

Preceding the *width* with a minus sign causes the output to be padded with spaces on the right, instead of on the left.

`.prec`
: A period followed by an integer constant specifies the precision to use when printing. The meaning of the precision varies by control letter:

`%d`, `%i`, `%o`, `%u`, `%x`, `%X`
: Minimum number of digits to print.

`%e`, `%E`, `%f`, `%F`
: Number of digits to the right of the decimal point.

`%g`, `%G`
: Maximum number of significant digits.

`%s`
: Maximum number of characters from the string that should print.

Thus, the following:

```
printf "%.4s", "foobar"
```

prints 'foob'.

The C library printf's dynamic *width* and *prec* capability (for example, "%*.*s") is supported. Instead of supplying explicit *width* and/or *prec* values in the format string, they are passed in the argument list. For example:

```
w = 5
p = 3
s = "abcdefg"
printf "%*.*s\n", w, p, s
```

is exactly equivalent to:

```
s = "abcdefg"
printf "%5.3s\n", s
```

Both programs output '••abc'. Earlier versions of awk did not support this capability. If you must use such a version, you may simulate this feature by using concatenation to build up the format string, like so:

```
w = 5
p = 3
s = "abcdefg"
printf "%" w "." p "s\n", s
```

This is not particularly easy to read but it does work.

C programmers may be used to supplying additional 'l', 'L', and 'h' modifiers in printf format strings. These are not valid in awk. Most awk implementations silently ignore them. If --lint is provided on the command line (see Section 2.2 [Command-Line Options], page 29), gawk warns about their use. If --posix is supplied, their use is a fatal error.

5.5.4 Examples Using printf

The following simple example shows how to use printf to make an aligned table:

```
awk '{ printf "%-10s %s\n", $1, $2 }' BBS-list
```

This command prints the names of the bulletin boards ($1) in the file BBS-list as a string of 10 characters that are left-justified. It also prints the phone numbers ($2) next on the line. This produces an aligned two-column table of names and phone numbers, as shown here:

```
$ awk '{ printf "%-10s %s\n", $1, $2 }' BBS-list
⊣ aardvark   555-5553
⊣ alpo-net   555-3412
⊣ barfly     555-7685
⊣ bites      555-1675
⊣ camelot    555-0542
⊣ core       555-2912
⊣ fooey      555-1234
⊣ foot       555-6699
⊣ macfoo     555-6480
⊣ sdace      555-3430
⊣ sabafoo    555-2127
```

In this case, the phone numbers had to be printed as strings because the numbers are separated by a dash. Printing the phone numbers as numbers would have produced just the first three digits: '555'. This would have been pretty confusing.

It wasn't necessary to specify a width for the phone numbers because they are last on their lines. They don't need to have spaces after them.

The table could be made to look even nicer by adding headings to the tops of the columns. This is done using the BEGIN pattern (see Section 7.1.4 [The BEGIN and END Special Patterns], page 122) so that the headers are only printed once, at the beginning of the awk program:

```
awk 'BEGIN { print "Name      Number"
             print "----      ------" }
      { printf "%-10s %s\n", $1, $2 }' BBS-list
```

The above example mixes print and printf statements in the same program. Using just printf statements can produce the same results:

```
awk 'BEGIN { printf "%-10s %s\n", "Name", "Number"
             printf "%-10s %s\n", "----", "------" }
      { printf "%-10s %s\n", $1, $2 }' BBS-list
```

Printing each column heading with the same format specification used for the column elements ensures that the headings are aligned just like the columns.

The fact that the same format specification is used three times can be emphasized by storing it in a variable, like this:

```
awk 'BEGIN { format = "%-10s %s\n"
             printf format, "Name", "Number"
             printf format, "----", "------" }
      { printf format, $1, $2 }' BBS-list
```

At this point, it would be a worthwhile exercise to use the printf statement to line up the headings and table data for the inventory-shipped example that was covered earlier in the section on the print statement (see Section 5.1 [The print Statement], page 81).

5.6 Redirecting Output of print and printf

So far, the output from print and printf has gone to the standard output, usually the screen. Both print and printf can also send their output to other places. This is called *redirection*.

> **NOTE:** When --sandbox is specified (see Section 2.2 [Command-Line Options], page 29), redirecting output to files and pipes is disabled.

A redirection appears after the print or printf statement. Redirections in awk are written just like redirections in shell commands, except that they are written inside the awk program.

There are four forms of output redirection: output to a file, output appended to a file, output through a pipe to another command, and output to a coprocess. They are all shown for the print statement, but they work identically for printf:

`print items > output-file`

This redirection prints the items into the output file named *output-file*. The file name *output-file* can be any expression. Its value is changed to a string and then used as a file name (see Chapter 6 [Expressions], page 97).

When this type of redirection is used, the *output-file* is erased before the first output is written to it. Subsequent writes to the same *output-file* do not erase *output-file*, but append to it. (This is different from how you use redirections in shell scripts.) If *output-file* does not exist, it is created. For example, here is how an `awk` program can write a list of BBS names to one file named `name-list`, and a list of phone numbers to another file named `phone-list`:

```
$ awk '{ print $2 > "phone-list"
>        print $1 > "name-list" }' BBS-list
$ cat phone-list
⊣ 555-5553
⊣ 555-3412
...
$ cat name-list
⊣ aardvark
⊣ alpo-net
...
```

Each output file contains one name or number per line.

`print items >> output-file`

This redirection prints the items into the pre-existing output file named *output-file*. The difference between this and the single-'`>`' redirection is that the old contents (if any) of *output-file* are not erased. Instead, the `awk` output is appended to the file. If *output-file* does not exist, then it is created.

`print items | command`

It is possible to send output to another program through a pipe instead of into a file. This redirection opens a pipe to *command*, and writes the values of *items* through this pipe to another process created to execute *command*.

The redirection argument *command* is actually an `awk` expression. Its value is converted to a string whose contents give the shell command to be run. For example, the following produces two files, one unsorted list of BBS names, and one list sorted in reverse alphabetical order:

```
awk '{ print $1 > "names.unsorted"
       command = "sort -r > names.sorted"
       print $1 | command }' BBS-list
```

The unsorted list is written with an ordinary redirection, while the sorted list is written by piping through the `sort` utility.

The next example uses redirection to mail a message to the mailing list '`bug-system`'. This might be useful when trouble is encountered in an `awk` script run periodically for system maintenance:

```
report = "mail bug-system"
print "Awk script failed:", $0 | report
```

```
m = ("at record number " FNR " of " FILENAME)
print m | report
close(report)
```

The message is built using string concatenation and saved in the variable `m`. It's then sent down the pipeline to the `mail` program. (The parentheses group the items to concatenate—see Section 6.2.2 [String Concatenation], page 104.)

The `close()` function is called here because it's a good idea to close the pipe as soon as all the intended output has been sent to it. See Section 5.8 [Closing Input and Output Redirections], page 94, for more information.

This example also illustrates the use of a variable to represent a *file* or *command*—it is not necessary to always use a string constant. Using a variable is generally a good idea, because (if you mean to refer to that same file or command) `awk` requires that the string value be spelled identically every time.

`print` *`items`* `|&` *`command`*

This redirection prints the items to the input of *command*. The difference between this and the single-'`|`' redirection is that the output from *command* can be read with `getline`. Thus *command* is a *coprocess*, which works together with, but subsidiary to, the `awk` program.

This feature is a `gawk` extension, and is not available in POSIX `awk`. See Section 4.9.7 [Using `getline` from a Coprocess], page 77, for a brief discussion. See Section 12.3 [Two-Way Communications with Another Process], page 283, for a more complete discussion.

Redirecting output using '`>`', '`>>`', '`|`', or '`|&`' asks the system to open a file, pipe, or coprocess only if the particular *file* or *command* you specify has not already been written to by your program or if it has been closed since it was last written to.

It is a common error to use '`>`' redirection for the first `print` to a file, and then to use '`>>`' for subsequent output:

```
# clear the file
print "Don't panic" > "guide.txt"
...
# append
print "Avoid improbability generators" >> "guide.txt"
```

This is indeed how redirections must be used from the shell. But in `awk`, it isn't necessary. In this kind of case, a program should use '`>`' for all the `print` statements, since the output file is only opened once. (It happens that if you mix '`>`' and '`>>`' that output is produced in the expected order. However, mixing the operators for the same file is definitely poor style, and is confusing to readers of your program.)

As mentioned earlier (see Section 4.9.9 [Points to Remember About `getline`], page 78), many older `awk` implementations limit the number of pipelines that an `awk` program may have open to just one! In `gawk`, there is no such limit. `gawk` allows a program to open as many pipelines as the underlying operating system permits.

Piping into sh

A particularly powerful way to use redirection is to build command lines and pipe them into the shell, `sh`. For example, suppose you have a list of files brought over from a system where all the file names are stored in uppercase, and you wish to rename them to have names in all lowercase. The following program is both simple and efficient:

```
{ printf("mv %s %s\n", $0, tolower($0)) | "sh" }

END { close("sh") }
```

The `tolower()` function returns its argument string with all uppercase characters converted to lowercase (see Section 9.1.3 [String-Manipulation Functions], page 161). The program builds up a list of command lines, using the `mv` utility to rename the files. It then sends the list to the shell for execution.

5.7 Special File Names in gawk

`gawk` provides a number of special file names that it interprets internally. These file names provide access to standard file descriptors and TCP/IP networking.

5.7.1 Special Files for Standard Descriptors

Running programs conventionally have three input and output streams already available to them for reading and writing. These are known as the *standard input*, *standard output*, and *standard error output*. These streams are, by default, connected to your keyboard and screen, but they are often redirected with the shell, via the '<', '<<', '>', '>>', '>&', and '|' operators. Standard error is typically used for writing error messages; the reason there are two separate streams, standard output and standard error, is so that they can be redirected separately.

In other implementations of `awk`, the only way to write an error message to standard error in an `awk` program is as follows:

```
print "Serious error detected!" | "cat 1>&2"
```

This works by opening a pipeline to a shell command that can access the standard error stream that it inherits from the `awk` process. This is far from elegant, and it is also inefficient, because it requires a separate process. So people writing `awk` programs often don't do this. Instead, they send the error messages to the screen, like this:

```
print "Serious error detected!" > "/dev/tty"
```

(`/dev/tty` is a special file supplied by the operating system that is connected to your keyboard and screen. It represents the "terminal,"[1] which on modern systems is a keyboard and screen, not a serial console.) This usually has the same effect but not always: although the standard error stream is usually the screen, it can be redirected; when that happens, writing to the screen is not correct. In fact, if `awk` is run from a background job, it may not have a terminal at all. Then opening `/dev/tty` fails.

`gawk` provides special file names for accessing the three standard streams. (c.e.). It also provides syntax for accessing any other inherited open files. If the file name matches one of these special names when `gawk` redirects input or output, then it directly uses the stream

[1] The "tty" in `/dev/tty` stands for "Teletype," a serial terminal.

that the file name stands for. These special file names work for all operating systems that `gawk` has been ported to, not just those that are POSIX-compliant:

`/dev/stdin`
: The standard input (file descriptor 0).

`/dev/stdout`
: The standard output (file descriptor 1).

`/dev/stderr`
: The standard error output (file descriptor 2).

`/dev/fd/`*N*
: The file associated with file descriptor *N*. Such a file must be opened by the program initiating the `awk` execution (typically the shell). Unless special pains are taken in the shell from which `gawk` is invoked, only descriptors 0, 1, and 2 are available.

The file names `/dev/stdin`, `/dev/stdout`, and `/dev/stderr` are aliases for `/dev/fd/0`, `/dev/fd/1`, and `/dev/fd/2`, respectively. However, they are more self-explanatory. The proper way to write an error message in a `gawk` program is to use `/dev/stderr`, like this:

```
print "Serious error detected!" > "/dev/stderr"
```

Note the use of quotes around the file name. Like any other redirection, the value must be a string. It is a common error to omit the quotes, which leads to confusing results.

Finally, using the `close()` function on a file name of the form `"/dev/fd/N"`, for file descriptor numbers above two, does actually close the given file descriptor.

The `/dev/stdin`, `/dev/stdout`, and `/dev/stderr` special files are also recognized internally by several other versions of `awk`.

5.7.2 Special Files for Network Communications

`gawk` programs can open a two-way TCP/IP connection, acting as either a client or a server. This is done using a special file name of the form:

```
/net-type/protocol/local-port/remote-host/remote-port
```

The *net-type* is one of '`inet`', '`inet4`' or '`inet6`'. The *protocol* is one of '`tcp`' or '`udp`', and the other fields represent the other essential pieces of information for making a networking connection. These file names are used with the '`|&`' operator for communicating with a coprocess (see Section 12.3 [Two-Way Communications with Another Process], page 283). This is an advanced feature, mentioned here only for completeness. Full discussion is delayed until Section 12.4 [Using `gawk` for Network Programming], page 285.

5.7.3 Special File Name Caveats

Here is a list of things to bear in mind when using the special file names that `gawk` provides:

- Recognition of these special file names is disabled if `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29).
- `gawk` *always* interprets these special file names. For example, using '`/dev/fd/4`' for output actually writes on file descriptor 4, and not on a new file descriptor that is `dup()`'ed from file descriptor 4. Most of the time this does not matter; however, it is important to *not* close any of the files related to file descriptors 0, 1, and 2. Doing so results in unpredictable behavior.

5.8 Closing Input and Output Redirections

If the same file name or the same shell command is used with `getline` more than once during the execution of an `awk` program (see Section 4.9 [Explicit Input with getline], page 73), the file is opened (or the command is executed) the first time only. At that time, the first record of input is read from that file or command. The next time the same file or command is used with `getline`, another record is read from it, and so on.

Similarly, when a file or pipe is opened for output, `awk` remembers the file name or command associated with it, and subsequent writes to the same file or command are appended to the previous writes. The file or pipe stays open until `awk` exits.

This implies that special steps are necessary in order to read the same file again from the beginning, or to rerun a shell command (rather than reading more output from the same command). The `close()` function makes these things possible:

```
close(filename)
```

or:

```
close(command)
```

The argument *filename* or *command* can be any expression. Its value must *exactly* match the string that was used to open the file or start the command (spaces and other "irrelevant" characters included). For example, if you open a pipe with this:

```
"sort -r names" | getline foo
```

then you must close it with this:

```
close("sort -r names")
```

Once this function call is executed, the next `getline` from that file or command, or the next `print` or `printf` to that file or command, reopens the file or reruns the command. Because the expression that you use to close a file or pipeline must exactly match the expression used to open the file or run the command, it is good practice to use a variable to store the file name or command. The previous example becomes the following:

```
sortcom = "sort -r names"
sortcom | getline foo
...
close(sortcom)
```

This helps avoid hard-to-find typographical errors in your `awk` programs. Here are some of the reasons for closing an output file:

- To write a file and read it back later on in the same `awk` program. Close the file after writing it, then begin reading it with `getline`.
- To write numerous files, successively, in the same `awk` program. If the files aren't closed, eventually `awk` may exceed a system limit on the number of open files in one process. It is best to close each one when the program has finished writing it.
- To make a command finish. When output is redirected through a pipe, the command reading the pipe normally continues to try to read input as long as the pipe is open. Often this means the command cannot really do its work until the pipe is closed. For example, if output is redirected to the `mail` program, the message is not actually sent until the pipe is closed.

- To run the same program a second time, with the same arguments. This is not the same thing as giving more input to the first run!

  For example, suppose a program pipes output to the `mail` program. If it outputs several lines redirected to this pipe without closing it, they make a single message of several lines. By contrast, if the program closes the pipe after each line of output, then each line makes a separate message.

If you use more files than the system allows you to have open, `gawk` attempts to multiplex the available open files among your data files. `gawk`'s ability to do this depends upon the facilities of your operating system, so it may not always work. It is therefore both good practice and good portability advice to always use `close()` on your files when you are done with them. In fact, if you are using a lot of pipes, it is essential that you close commands when done. For example, consider something like this:

```
{
    ...
    command = ("grep " $1 " /some/file | my_prog -q " $3)
    while ((command | getline) > 0) {
        process output of command
    }
    # need close(command) here
}
```

This example creates a new pipeline based on data in *each* record. Without the call to `close()` indicated in the comment, `awk` creates child processes to run the commands, until it eventually runs out of file descriptors for more pipelines.

Even though each command has finished (as indicated by the end-of-file return status from `getline`), the child process is not terminated;[2] more importantly, the file descriptor for the pipe is not closed and released until `close()` is called or `awk` exits.

`close()` will silently do nothing if given an argument that does not represent a file, pipe or coprocess that was opened with a redirection.

Note also that '`close(FILENAME)`' has no "magic" effects on the implicit loop that reads through the files named on the command line. It is, more likely, a close of a file that was never opened, so `awk` silently does nothing.

When using the '`|&`' operator to communicate with a coprocess, it is occasionally useful to be able to close one end of the two-way pipe without closing the other. This is done by supplying a second argument to `close()`. As in any other call to `close()`, the first argument is the name of the command or special file used to start the coprocess. The second argument should be a string, with either of the values `"to"` or `"from"`. Case does not matter. As this is an advanced feature, a more complete discussion is delayed until Section 12.3 [Two-Way Communications with Another Process], page 283, which discusses it in more detail and gives an example.

[2] The technical terminology is rather morbid. The finished child is called a "zombie," and cleaning up after it is referred to as "reaping."

Using `close()`'s Return Value

In many versions of Unix `awk`, the `close()` function is actually a statement. It is a syntax error to try and use the return value from `close()`:

```
command = "..."
command | getline info
retval = close(command)  # syntax error in many Unix awks
```

`gawk` treats `close()` as a function. The return value is −1 if the argument names something that was never opened with a redirection, or if there is a system problem closing the file or process. In these cases, `gawk` sets the built-in variable `ERRNO` to a string describing the problem.

In `gawk`, when closing a pipe or coprocess (input or output), the return value is the exit status of the command.[3] Otherwise, it is the return value from the system's `close()` or `fclose()` C functions when closing input or output files, respectively. This value is zero if the close succeeds, or −1 if it fails.

The POSIX standard is very vague; it says that `close()` returns zero on success and nonzero otherwise. In general, different implementations vary in what they report when closing pipes; thus the return value cannot be used portably. In POSIX mode (see Section 2.2 [Command-Line Options], page 29), `gawk` just returns zero when closing a pipe.

[3] This is a full 16-bit value as returned by the `wait()` system call. See the system manual pages for information on how to decode this value.

6 Expressions

Expressions are the basic building blocks of `awk` patterns and actions. An expression evaluates to a value that you can print, test, or pass to a function. Additionally, an expression can assign a new value to a variable or a field by using an assignment operator.

An expression can serve as a pattern or action statement on its own. Most other kinds of statements contain one or more expressions that specify the data on which to operate. As in other languages, expressions in `awk` include variables, array references, constants, and function calls, as well as combinations of these with various operators.

6.1 Constants, Variables and Conversions

Expressions are built up from values and the operations performed upon them. This section describes the elementary objects which provide the values used in expressions.

6.1.1 Constant Expressions

The simplest type of expression is the *constant*, which always has the same value. There are three types of constants: numeric, string, and regular expression.

Each is used in the appropriate context when you need a data value that isn't going to change. Numeric constants can have different forms, but are stored identically internally.

6.1.1.1 Numeric and String Constants

A *numeric constant* stands for a number. This number can be an integer, a decimal fraction, or a number in scientific (exponential) notation.[1] Here are some examples of numeric constants that all have the same value:

```
105
1.05e+2
1050e-1
```

A string constant consists of a sequence of characters enclosed in double-quotation marks. For example:

```
"parrot"
```

represents the string whose contents are '`parrot`'. Strings in `gawk` can be of any length, and they can contain any of the possible eight-bit ASCII characters including ASCII NUL (character code zero). Other `awk` implementations may have difficulty with some character codes.

6.1.1.2 Octal and Hexadecimal Numbers

In `awk`, all numbers are in decimal; i.e., base 10. Many other programming languages allow you to specify numbers in other bases, often octal (base 8) and hexadecimal (base 16). In octal, the numbers go 0, 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, etc. Just as '`11`', in decimal, is 1 times 10 plus 1, so '`11`', in octal, is 1 times 8, plus 1. This equals 9 in decimal. In hexadecimal, there are 16 digits. Since the everyday decimal number system only has ten digits ('`0`'–'`9`'), the letters '`a`' through '`f`' are used to represent the rest. (Case in the letters is usually

[1] The internal representation of all numbers, including integers, uses double precision floating-point numbers. On most modern systems, these are in IEEE 754 standard format.

irrelevant; hexadecimal 'a' and 'A' have the same value.) Thus, '11', in hexadecimal, is 1 times 16 plus 1, which equals 17 in decimal.

Just by looking at plain '11', you can't tell what base it's in. So, in C, C++, and other languages derived from C, there is a special notation to signify the base. Octal numbers start with a leading '0', and hexadecimal numbers start with a leading '0x' or '0X':

`11` Decimal value 11.

`011` Octal 11, decimal value 9.

`0x11` Hexadecimal 11, decimal value 17.

This example shows the difference:

```
$ gawk 'BEGIN { printf "%d, %d, %d\n", 011, 11, 0x11 }'
⊣ 9, 11, 17
```

Being able to use octal and hexadecimal constants in your programs is most useful when working with data that cannot be represented conveniently as characters or as regular numbers, such as binary data of various sorts.

`gawk` allows the use of octal and hexadecimal constants in your program text. However, such numbers in the input data are not treated differently; doing so by default would break old programs. (If you really need to do this, use the `--non-decimal-data` command-line option; see Section 12.1 [Allowing Nondecimal Input Data], page 277.) If you have octal or hexadecimal data, you can use the `strtonum()` function (see Section 9.1.3 [String-Manipulation Functions], page 161) to convert the data into a number. Most of the time, you will want to use octal or hexadecimal constants when working with the built-in bit manipulation functions; see Section 9.1.6 [Bit-Manipulation Functions], page 181, for more information.

Unlike some early C implementations, '8' and '9' are not valid in octal constants; e.g., `gawk` treats '018' as decimal 18:

```
$ gawk 'BEGIN { print "021 is", 021 ; print 018 }'
⊣ 021 is 17
⊣ 18
```

Octal and hexadecimal source code constants are a `gawk` extension. If `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), they are not available.

A Constant's Base Does Not Affect Its Value

Once a numeric constant has been converted internally into a number, `gawk` no longer remembers what the original form of the constant was; the internal value is always used. This has particular consequences for conversion of numbers to strings:

```
$ gawk 'BEGIN { printf "0x11 is <%s>\n", 0x11 }'
⊣ 0x11 is <17>
```

6.1.1.3 Regular Expression Constants

A regexp constant is a regular expression description enclosed in slashes, such as `/^beginning and end$/`. Most regexps used in `awk` programs are constant, but the '~' and '!~' matching operators can also match computed or dynamic regexps (which are just ordinary strings or variables that contain a regexp).

6.1.2 Using Regular Expression Constants

When used on the righthand side of the '~' or '!~' operators, a regexp constant merely stands for the regexp that is to be matched. However, regexp constants (such as /foo/) may be used like simple expressions. When a regexp constant appears by itself, it has the same meaning as if it appeared in a pattern, i.e., '($0 ~ /foo/)' See Section 7.1.2 [Expressions as Patterns], page 119. This means that the following two code segments:

```
if ($0 ~ /barfly/ || $0 ~ /camelot/)
    print "found"
```

and:

```
if (/barfly/ || /camelot/)
    print "found"
```

are exactly equivalent. One rather bizarre consequence of this rule is that the following Boolean expression is valid, but does not do what the user probably intended:

```
# Note that /foo/ is on the left of the ~
if (/foo/ ~ $1) print "found foo"
```

This code is "obviously" testing $1 for a match against the regexp /foo/. But in fact, the expression '/foo/ ~ $1' really means '($0 ~ /foo/) ~ $1'. In other words, first match the input record against the regexp /foo/. The result is either zero or one, depending upon the success or failure of the match. That result is then matched against the first field in the record. Because it is unlikely that you would ever really want to make this kind of test, gawk issues a warning when it sees this construct in a program. Another consequence of this rule is that the assignment statement:

```
matches = /foo/
```

assigns either zero or one to the variable matches, depending upon the contents of the current input record.

Constant regular expressions are also used as the first argument for the gensub(), sub(), and gsub() functions, as the second argument of the match() function, and as the third argument of the patsplit() function (see Section 9.1.3 [String-Manipulation Functions], page 161). Modern implementations of awk, including gawk, allow the third argument of split() to be a regexp constant, but some older implementations do not. This can lead to confusion when attempting to use regexp constants as arguments to user-defined functions (see Section 9.2 [User-Defined Functions], page 184). For example:

```
function mysub(pat, repl, str, global)
{
    if (global)
        gsub(pat, repl, str)
    else
        sub(pat, repl, str)
    return str
}

{
    ...
    text = "hi! hi yourself!"
```

```
        mysub(/hi/, "howdy", text, 1)
        ...
    }
```

In this example, the programmer wants to pass a regexp constant to the user-defined function `mysub`, which in turn passes it on to either `sub()` or `gsub()`. However, what really happens is that the `pat` parameter is either one or zero, depending upon whether or not `$0` matches `/hi/`. `gawk` issues a warning when it sees a regexp constant used as a parameter to a user-defined function, since passing a truth value in this way is probably not what was intended.

6.1.3 Variables

Variables are ways of storing values at one point in your program for use later in another part of your program. They can be manipulated entirely within the program text, and they can also be assigned values on the `awk` command line.

6.1.3.1 Using Variables in a Program

Variables let you give names to values and refer to them later. Variables have already been used in many of the examples. The name of a variable must be a sequence of letters, digits, or underscores, and it may not begin with a digit. Case is significant in variable names; `a` and `A` are distinct variables.

A variable name is a valid expression by itself; it represents the variable's current value. Variables are given new values with *assignment operators*, *increment operators*, and *decrement operators*. See Section 6.2.3 [Assignment Expressions], page 106. In addition, the `sub()` and `gsub()` functions can change a variable's value, and the `match()`, `patsplit()` and `split()` functions can change the contents of their array parameters. See Section 9.1.3 [String-Manipulation Functions], page 161.

A few variables have special built-in meanings, such as `FS` (the field separator), and `NF` (the number of fields in the current input record). See Section 7.5 [Built-in Variables], page 134, for a list of the built-in variables. These built-in variables can be used and assigned just like all other variables, but their values are also used or changed automatically by `awk`. All built-in variables' names are entirely uppercase.

Variables in `awk` can be assigned either numeric or string values. The kind of value a variable holds can change over the life of a program. By default, variables are initialized to the empty string, which is zero if converted to a number. There is no need to explicitly "initialize" a variable in `awk`, which is what you would do in C and in most other traditional languages.

6.1.3.2 Assigning Variables on the Command Line

Any `awk` variable can be set by including a *variable assignment* among the arguments on the command line when `awk` is invoked (see Section 2.3 [Other Command-Line Arguments], page 35). Such an assignment has the following form:

```
variable=text
```

With it, a variable is set either at the beginning of the `awk` run or in between input files. When the assignment is preceded with the `-v` option, as in the following:

```
-v variable=text
```

the variable is set at the very beginning, even before the BEGIN rules execute. The -v option and its assignment must precede all the file name arguments, as well as the program text. (See Section 2.2 [Command-Line Options], page 29, for more information about the -v option.) Otherwise, the variable assignment is performed at a time determined by its position among the input file arguments—after the processing of the preceding input file argument. For example:

```
awk '{ print $n }' n=4 inventory-shipped n=2 BBS-list
```

prints the value of field number n for all input records. Before the first file is read, the command line sets the variable n equal to four. This causes the fourth field to be printed in lines from inventory-shipped. After the first file has finished, but before the second file is started, n is set to two, so that the second field is printed in lines from BBS-list:

```
$ awk '{ print $n }' n=4 inventory-shipped n=2 BBS-list
⊣ 15
⊣ 24
...
⊣ 555-5553
⊣ 555-3412
...
```

Command-line arguments are made available for explicit examination by the awk program in the ARGV array (see Section 7.5.3 [Using ARGC and ARGV], page 143). awk processes the values of command-line assignments for escape sequences (see Section 3.2 [Escape Sequences], page 44).

6.1.4 Conversion of Strings and Numbers

Strings are converted to numbers and numbers are converted to strings, if the context of the awk program demands it. For example, if the value of either foo or bar in the expression 'foo + bar' happens to be a string, it is converted to a number before the addition is performed. If numeric values appear in string concatenation, they are converted to strings. Consider the following:

```
two = 2; three = 3
print (two three) + 4
```

This prints the (numeric) value 27. The numeric values of the variables two and three are converted to strings and concatenated together. The resulting string is converted back to the number 23, to which 4 is then added.

If, for some reason, you need to force a number to be converted to a string, concatenate that number with the empty string, "". To force a string to be converted to a number, add zero to that string. A string is converted to a number by interpreting any numeric prefix of the string as numerals: "2.5" converts to 2.5, "1e3" converts to 1000, and "25fix" has a numeric value of 25. Strings that can't be interpreted as valid numbers convert to zero.

The exact manner in which numbers are converted into strings is controlled by the awk built-in variable CONVFMT (see Section 7.5 [Built-in Variables], page 134). Numbers are converted using the sprintf() function with CONVFMT as the format specifier (see Section 9.1.3 [String-Manipulation Functions], page 161).

CONVFMT's default value is "%.6g", which creates a value with at most six significant digits. For some applications, you might want to change it to specify more precision. On most modern machines, 17 digits is usually enough to capture a floating-point number's value exactly.[2]

Strange results can occur if you set `CONVFMT` to a string that doesn't tell `sprintf()` how to format floating-point numbers in a useful way. For example, if you forget the '`%`' in the format, `awk` converts all numbers to the same constant string.

As a special case, if a number is an integer, then the result of converting it to a string is *always* an integer, no matter what the value of `CONVFMT` may be. Given the following code fragment:

```
CONVFMT = "%2.2f"
a = 12
b = a ""
```

`b` has the value `"12"`, not `"12.00"`.

Prior to the POSIX standard, `awk` used the value of `OFMT` for converting numbers to strings. `OFMT` specifies the output format to use when printing numbers with `print`. `CONVFMT` was introduced in order to separate the semantics of conversion from the semantics of printing. Both `CONVFMT` and `OFMT` have the same default value: `"%.6g"`. In the vast majority of cases, old `awk` programs do not change their behavior. However, these semantics for `OFMT` are something to keep in mind if you must port your new-style program to older implementations of `awk`. We recommend that instead of changing your programs, just port `gawk` itself. See Section 5.1 [The `print` Statement], page 81, for more information on the `print` statement.

And, once again, where you are can matter when it comes to converting between numbers and strings. In Section 6.6 [Where You Are Makes A Difference], page 118, we mentioned that the local character set and language (the locale) can affect how `gawk` matches characters. The locale also affects numeric formats. In particular, for `awk` programs, it affects the decimal point character. The `"C"` locale, and most English-language locales, use the period character ('`.`') as the decimal point. However, many (if not most) European and non-English locales use the comma ('`,`') as the decimal point character.

The POSIX standard says that `awk` always uses the period as the decimal point when reading the `awk` program source code, and for command-line variable assignments (see Section 2.3 [Other Command-Line Arguments], page 35). However, when interpreting input data, for `print` and `printf` output, and for number to string conversion, the local decimal point character is used. . Here are some examples indicating the difference in behavior, on a GNU/Linux system:

```
$ export POSIXLY_CORRECT=1                          Force POSIX behavior
$ gawk 'BEGIN { printf "%g\n", 3.1415927 }'
⊣ 3.14159
$ LC_ALL=en_DK.utf-8 gawk 'BEGIN { printf "%g\n", 3.1415927 }'
⊣ 3,14159
$ echo 4,321 | gawk '{ print $1 + 1 }'
⊣ 5
$ echo 4,321 | LC_ALL=en_DK.utf-8 gawk '{ print $1 + 1 }'
⊣ 5,321
```

[2] Pathological cases can require up to 752 digits (!), but we doubt that you need to worry about this.

The 'en_DK.utf-8' locale is for English in Denmark, where the comma acts as the decimal point separator. In the normal "C" locale, gawk treats '4,321' as '4', while in the Danish locale, it's treated as the full number, 4.321.

Some earlier versions of gawk fully complied with this aspect of the standard. However, many users in non-English locales complained about this behavior, since their data used a period as the decimal point, so the default behavior was restored to use a period as the decimal point character. You can use the --use-lc-numeric option (see Section 2.2 [Command-Line Options], page 29) to force gawk to use the locale's decimal point character. (gawk also uses the locale's decimal point character when in POSIX mode, either via --posix, or the POSIXLY_CORRECT environment variable, as shown previously.)

Table 6.1 describes the cases in which the locale's decimal point character is used and when a period is used. Some of these features have not been described yet.

Feature	Default	--posix or --use-lc-numeric
%'g	Use locale	Use locale
%g	Use period	Use locale
Input	Use period	Use locale
strtonum()	Use period	Use locale

Table 6.1: Locale Decimal Point versus A Period

Finally, modern day formal standards and IEEE standard floating point representation can have an unusual but important effect on the way gawk converts some special string values to numbers. The details are presented in Section 15.1.1.3 [Standards Versus Existing Practice], page 319.

6.2 Operators: Doing Something With Values

This section introduces the *operators* which make use of the values provided by constants and variables.

6.2.1 Arithmetic Operators

The awk language uses the common arithmetic operators when evaluating expressions. All of these arithmetic operators follow normal precedence rules and work as you would expect them to.

The following example uses a file named grades, which contains a list of student names as well as three test scores per student (it's a small class):

```
Pat   100 97 58
Sandy  84 72 93
Chris  72 92 89
```

This program takes the file grades and prints the average of the scores:

```
$ awk '{ sum = $2 + $3 + $4 ; avg = sum / 3
>        print $1, avg }' grades
⊣ Pat 85
⊣ Sandy 83
⊣ Chris 84.3333
```

The following list provides the arithmetic operators in `awk`, in order from the highest precedence to the lowest:

x `^` *y*
x `**` *y*
: Exponentiation; *x* raised to the *y* power. '`2 ^ 3`' has the value eight; the character sequence '`**`' is equivalent to '`^`'. (c.e.)

`-` *x*
: Negation.

`+` *x*
: Unary plus; the expression is converted to a number.

x `*` *y*
: Multiplication.

x `/` *y*
: Division; because all numbers in `awk` are floating-point numbers, the result is *not* rounded to an integer—'`3 / 4`' has the value 0.75. (It is a common mistake, especially for C programmers, to forget that *all* numbers in `awk` are floating-point, and that division of integer-looking constants produces a real number, not an integer.)

x `%` *y*
: Remainder; further discussion is provided in the text, just after this list.

x `+` *y*
: Addition.

x `-` *y*
: Subtraction.

Unary plus and minus have the same precedence, the multiplication operators all have the same precedence, and addition and subtraction have the same precedence.

When computing the remainder of '*x* `%` *y*', the quotient is rounded toward zero to an integer and multiplied by *y*. This result is subtracted from *x*; this operation is sometimes known as "trunc-mod." The following relation always holds:

```
b * int(a / b) + (a % b) == a
```

One possibly undesirable effect of this definition of remainder is that *x* `%` *y* is negative if *x* is negative. Thus:

```
-17 % 8 = -1
```

In other `awk` implementations, the signedness of the remainder may be machine-dependent.

> **NOTE:** The POSIX standard only specifies the use of '`^`' for exponentiation. For maximum portability, do not use the '`**`' operator.

6.2.2 String Concatenation

> *It seemed like a good idea at the time.*
> Brian Kernighan

There is only one string operation: concatenation. It does not have a specific operator to represent it. Instead, concatenation is performed by writing expressions next to one another, with no operator. For example:

```
$ awk '{ print "Field number one: " $1 }' BBS-list
⊣ Field number one: aardvark
⊣ Field number one: alpo-net
...
```

Without the space in the string constant after the '`:`', the line runs together. For example:

```
$ awk '{ print "Field number one:" $1 }' BBS-list
⊣ Field number one:aardvark
⊣ Field number one:alpo-net
...
```

Because string concatenation does not have an explicit operator, it is often necessary to insure that it happens at the right time by using parentheses to enclose the items to concatenate. For example, you might expect that the following code fragment concatenates `file` and `name`:

```
file = "file"
name = "name"
print "something meaningful" > file name
```

This produces a syntax error with some versions of Unix `awk`.[3] It is necessary to use the following:

```
print "something meaningful" > (file name)
```

Parentheses should be used around concatenation in all but the most common contexts, such as on the righthand side of '`=`'. Be careful about the kinds of expressions used in string concatenation. In particular, the order of evaluation of expressions used for concatenation is undefined in the `awk` language. Consider this example:

```
BEGIN {
    a = "don't"
    print (a " " (a = "panic"))
}
```

It is not defined whether the assignment to `a` happens before or after the value of `a` is retrieved for producing the concatenated value. The result could be either '`don't panic`', or '`panic panic`'.

The precedence of concatenation, when mixed with other operators, is often counter-intuitive. Consider this example:

```
$ awk 'BEGIN { print -12 " " -24 }'
⊣ -12-24
```

This "obviously" is concatenating −12, a space, and −24. But where did the space disappear to? The answer lies in the combination of operator precedences and `awk`'s automatic conversion rules. To get the desired result, write the program this way:

```
$ awk 'BEGIN { print -12 " " (-24) }'
⊣ -12 -24
```

This forces `awk` to treat the '`-`' on the '`-24`' as unary. Otherwise, it's parsed as follows:

```
   −12 (" " − 24)
⇒ −12 (0 − 24)
⇒ −12 (−24)
⇒ −12−24
```

As mentioned earlier, when doing concatenation, *parenthesize*. Otherwise, you're never quite sure what you'll get.

[3] It happens that Brian Kernighan's `awk`, `gawk` and `mawk` all "get it right," but you should not rely on this.

6.2.3 Assignment Expressions

An *assignment* is an expression that stores a (usually different) value into a variable. For example, let's assign the value one to the variable `z`:

```
z = 1
```

After this expression is executed, the variable `z` has the value one. Whatever old value `z` had before the assignment is forgotten.

Assignments can also store string values. For example, the following stores the value `"this food is good"` in the variable `message`:

```
thing = "food"
predicate = "good"
message = "this " thing " is " predicate
```

This also illustrates string concatenation. The '`=`' sign is called an *assignment operator*. It is the simplest assignment operator because the value of the righthand operand is stored unchanged. Most operators (addition, concatenation, and so on) have no effect except to compute a value. If the value isn't used, there's no reason to use the operator. An assignment operator is different; it does produce a value, but even if you ignore it, the assignment still makes itself felt through the alteration of the variable. We call this a *side effect*.

The lefthand operand of an assignment need not be a variable (see Section 6.1.3 [Variables], page 100); it can also be a field (see Section 4.4 [Changing the Contents of a Field], page 60) or an array element (see Chapter 8 [Arrays in `awk`], page 145). These are all called *lvalues*, which means they can appear on the lefthand side of an assignment operator. The righthand operand may be any expression; it produces the new value that the assignment stores in the specified variable, field, or array element. (Such values are called *rvalues*.)

It is important to note that variables do *not* have permanent types. A variable's type is simply the type of whatever value it happens to hold at the moment. In the following program fragment, the variable `foo` has a numeric value at first, and a string value later on:

```
foo = 1
print foo
foo = "bar"
print foo
```

When the second assignment gives `foo` a string value, the fact that it previously had a numeric value is forgotten.

String values that do not begin with a digit have a numeric value of zero. After executing the following code, the value of `foo` is five:

```
foo = "a string"
foo = foo + 5
```

> **NOTE:** Using a variable as a number and then later as a string can be confusing and is poor programming style. The previous two examples illustrate how `awk` works, *not* how you should write your programs!

An assignment is an expression, so it has a value—the same value that is assigned. Thus, '`z = 1`' is an expression with the value one. One consequence of this is that you can write multiple assignments together, such as:

```
x = y = z = 5
```

This example stores the value five in all three variables (`x`, `y`, and `z`). It does so because the value of '`z = 5`', which is five, is stored into `y` and then the value of '`y = z = 5`', which is five, is stored into `x`.

Assignments may be used anywhere an expression is called for. For example, it is valid to write '`x != (y = 1)`' to set `y` to one, and then test whether `x` equals one. But this style tends to make programs hard to read; such nesting of assignments should be avoided, except perhaps in a one-shot program.

Aside from '`=`', there are several other assignment operators that do arithmetic with the old value of the variable. For example, the operator '`+=`' computes a new value by adding the righthand value to the old value of the variable. Thus, the following assignment adds five to the value of `foo`:

```
foo += 5
```

This is equivalent to the following:

```
foo = foo + 5
```

Use whichever makes the meaning of your program clearer.

There are situations where using '`+=`' (or any assignment operator) is *not* the same as simply repeating the lefthand operand in the righthand expression. For example:

```
# Thanks to Pat Rankin for this example
BEGIN  {
    foo[rand()] += 5
    for (x in foo)
       print x, foo[x]

    bar[rand()] = bar[rand()] + 5
    for (x in bar)
       print x, bar[x]
}
```

The indices of `bar` are practically guaranteed to be different, because `rand()` returns different values each time it is called. (Arrays and the `rand()` function haven't been covered yet. See Chapter 8 [Arrays in `awk`], page 145, and see Section 9.1.2 [Numeric Functions], page 159, for more information). This example illustrates an important fact about assignment operators: the lefthand expression is only evaluated *once*. It is up to the implementation as to which expression is evaluated first, the lefthand or the righthand. Consider this example:

```
i = 1
a[i += 2] = i + 1
```

The value of `a[3]` could be either two or four.

Table 6.2 lists the arithmetic assignment operators. In each case, the righthand operand is an expression whose value is converted to a number.

Operator	Effect
lvalue += *increment*	Adds *increment* to the value of *lvalue*.
lvalue -= *decrement*	Subtracts *decrement* from the value of *lvalue*.
lvalue *= *coefficient*	Multiplies the value of *lvalue* by *coefficient*.
lvalue /= *divisor*	Divides the value of *lvalue* by *divisor*.
lvalue %= *modulus*	Sets *lvalue* to its remainder by *modulus*.
lvalue ^= *power*	
lvalue **= *power*	Raises *lvalue* to the power *power*. (c.e.)

Table 6.2: Arithmetic Assignment Operators

> **NOTE:** Only the '^=' operator is specified by POSIX. For maximum portability, do not use the '**=' operator.

Syntactic Ambiguities Between '/=' and Regular Expressions

There is a syntactic ambiguity between the `/=` assignment operator and regexp constants whose first character is an '='. This is most notable in some commercial `awk` versions. For example:

```
$ awk /==/ /dev/null
error  awk: syntax error at source line 1
error   context is
error          >>> /= <<<
error  awk: bailing out at source line 1
```

A workaround is:

```
awk '/[=]=/' /dev/null
```

`gawk` does not have this problem, nor do the other freely available versions described in Section B.5 [Other Freely Available `awk` Implementations], page 412.

6.2.4 Increment and Decrement Operators

Increment and *decrement operators* increase or decrease the value of a variable by one. An assignment operator can do the same thing, so the increment operators add no power to the `awk` language; however, they are convenient abbreviations for very common operations.

The operator used for adding one is written '`++`'. It can be used to increment a variable either before or after taking its value. To pre-increment a variable `v`, write '`++v`'. This adds one to the value of `v`—that new value is also the value of the expression. (The assignment expression '`v += 1`' is completely equivalent.) Writing the '`++`' after the variable specifies post-increment. This increments the variable value just the same; the difference is that the value of the increment expression itself is the variable's *old* value. Thus, if `foo` has the value four, then the expression '`foo++`' has the value four, but it changes the value of `foo` to five. In other words, the operator returns the old value of the variable, but with the side effect of incrementing it.

The post-increment '`foo++`' is nearly the same as writing '`(foo += 1) - 1`'. It is not perfectly equivalent because all numbers in `awk` are floating-point—in floating-point, '`foo`

`+ 1 - 1`' does not necessarily equal `foo`. But the difference is minute as long as you stick to numbers that are fairly small (less than 10e12).

Fields and array elements are incremented just like variables. (Use '`$(i++)`' when you want to do a field reference and a variable increment at the same time. The parentheses are necessary because of the precedence of the field reference operator '`$`'.)

The decrement operator '`--`' works just like '`++`', except that it subtracts one instead of adding it. As with '`++`', it can be used before the lvalue to pre-decrement or after it to post-decrement. Following is a summary of increment and decrement expressions:

`++lvalue` Increment *lvalue*, returning the new value as the value of the expression.

`lvalue++` Increment *lvalue*, returning the *old* value of *lvalue* as the value of the expression.

`--lvalue` Decrement *lvalue*, returning the new value as the value of the expression. (This expression is like '`++lvalue`', but instead of adding, it subtracts.)

`lvalue--` Decrement *lvalue*, returning the *old* value of *lvalue* as the value of the expression. (This expression is like '`lvalue++`', but instead of adding, it subtracts.)

Operator Evaluation Order

Doctor, doctor! It hurts when I do this!
So don't do that!
Groucho Marx

What happens for something like the following?

```
b = 6
print b += b++
```

Or something even stranger?

```
b = 6
b += ++b + b++
print b
```

In other words, when do the various side effects prescribed by the postfix operators ('`b++`') take effect? When side effects happen is *implementation defined*. In other words, it is up to the particular version of `awk`. The result for the first example may be 12 or 13, and for the second, it may be 22 or 23.

In short, doing things like this is not recommended and definitely not anything that you can rely upon for portability. You should avoid such things in your own programs.

6.3 Truth Values and Conditions

In certain contexts, expression values also serve as "truth values;" i.e., they determine what should happen next as the program runs. This section describes how `awk` defines "true" and "false" and how values are compared.

6.3.1 True and False in awk

Many programming languages have a special representation for the concepts of "true" and "false." Such languages usually use the special constants `true` and `false`, or perhaps their uppercase equivalents. However, `awk` is different. It borrows a very simple concept of true and false from C. In `awk`, any nonzero numeric value *or* any nonempty string value is true. Any other value (zero or the null string, `""`) is false. The following program prints '`A strange truth value`' three times:

```
BEGIN {
   if (3.1415927)
       print "A strange truth value"
   if ("Four Score And Seven Years Ago")
       print "A strange truth value"
   if (j = 57)
       print "A strange truth value"
}
```

There is a surprising consequence of the "nonzero or non-null" rule: the string constant `"0"` is actually true, because it is non-null.

6.3.2 Variable Typing and Comparison Expressions

The Guide is definitive. Reality is frequently inaccurate.
The Hitchhiker's Guide to the Galaxy

Unlike other programming languages, `awk` variables do not have a fixed type. Instead, they can be either a number or a string, depending upon the value that is assigned to them. We look now at how variables are typed, and how `awk` compares variables.

6.3.2.1 String Type Versus Numeric Type

The 1992 POSIX standard introduced the concept of a *numeric string*, which is simply a string that looks like a number—for example, `" +2"`. This concept is used for determining the type of a variable. The type of the variable is important because the types of two variables determine how they are compared. The various versions of the POSIX standard did not get the rules quite right for several editions. Fortunately, as of at least the 2008 standard (and possibly earlier), the standard has been fixed, and variable typing follows these rules:[4]

- A numeric constant or the result of a numeric operation has the *numeric* attribute.
- A string constant or the result of a string operation has the *string* attribute.
- Fields, `getline` input, `FILENAME`, `ARGV` elements, `ENVIRON` elements, and the elements of an array created by `patsplit()`, `split()` and `match()` that are numeric strings have the *strnum* attribute. Otherwise, they have the *string* attribute. Uninitialized variables also have the *strnum* attribute.
- Attributes propagate across assignments but are not changed by any use.

The last rule is particularly important. In the following program, `a` has numeric type, even though it is later used in a string operation:

```
BEGIN {
      a = 12.345
      b = a " is a cute number"
```

[4] `gawk` has followed these rules for many years, and it is gratifying that the POSIX standard is also now correct.

```
        print b
}
```

When two operands are compared, either string comparison or numeric comparison may be used. This depends upon the attributes of the operands, according to the following symmetric matrix:

	STRING	NUMERIC	STRNUM
STRING	string	string	string
NUMERIC	string	numeric	numeric
STRNUM	string	numeric	numeric

The basic idea is that user input that looks numeric—and *only* user input—should be treated as numeric, even though it is actually made of characters and is therefore also a string. Thus, for example, the string constant `" +3.14"`, when it appears in program source code, is a string—even though it looks numeric—and is *never* treated as number for comparison purposes.

In short, when one operand is a "pure" string, such as a string constant, then a string comparison is performed. Otherwise, a numeric comparison is performed.

This point bears additional emphasis: All user input is made of characters, and so is first and foremost of *string* type; input strings that look numeric are additionally given the *strnum* attribute. Thus, the six-character input string '` +3.14`' receives the *strnum* attribute. In contrast, the eight-character literal `" +3.14"` appearing in program text is a string constant. The following examples print '`1`' when the comparison between the two different constants is true, '`0`' otherwise:

```
$ echo ' +3.14' | gawk '{ print $0 == " +3.14" }'      True
⊣ 1
$ echo ' +3.14' | gawk '{ print $0 == "+3.14" }'       False
⊣ 0
$ echo ' +3.14' | gawk '{ print $0 == "3.14" }'        False
⊣ 0
$ echo ' +3.14' | gawk '{ print $0 == 3.14 }'          True
⊣ 1
$ echo ' +3.14' | gawk '{ print $1 == " +3.14" }'      False
⊣ 0
$ echo ' +3.14' | gawk '{ print $1 == "+3.14" }'       True
⊣ 1
$ echo ' +3.14' | gawk '{ print $1 == "3.14" }'        False
⊣ 0
$ echo ' +3.14' | gawk '{ print $1 == 3.14 }'          True
⊣ 1
```

6.3.2.2 Comparison Operators

Comparison expressions compare strings or numbers for relationships such as equality. They are written using *relational operators*, which are a superset of those in C. Table 6.3 describes them.

Expression	**Result**
x `<` *y*	True if *x* is less than *y*.
x `<=` *y*	True if *x* is less than or equal to *y*.
x `>` *y*	True if *x* is greater than *y*.
x `>=` *y*	True if *x* is greater than or equal to *y*.
x `==` *y*	True if *x* is equal to *y*.
x `!=` *y*	True if *x* is not equal to *y*.
x `~` *y*	True if the string *x* matches the regexp denoted by *y*.
x `!~` *y*	True if the string *x* does not match the regexp denoted by *y*.
subscript `in` *array*	True if the array *array* has an element with the subscript *subscript*.

Table 6.3: Relational Operators

Comparison expressions have the value one if true and zero if false. When comparing operands of mixed types, numeric operands are converted to strings using the value of `CONVFMT` (see Section 6.1.4 [Conversion of Strings and Numbers], page 101).

Strings are compared by comparing the first character of each, then the second character of each, and so on. Thus, `"10"` is less than `"9"`. If there are two strings where one is a prefix of the other, the shorter string is less than the longer one. Thus, `"abc"` is less than `"abcd"`.

It is very easy to accidentally mistype the '`==`' operator and leave off one of the '`=`' characters. The result is still valid `awk` code, but the program does not do what is intended:

```
if (a = b)   # oops! should be a == b
   ...
else
   ...
```

Unless `b` happens to be zero or the null string, the `if` part of the test always succeeds. Because the operators are so similar, this kind of error is very difficult to spot when scanning the source code.

The following table of expressions illustrates the kind of comparison `gawk` performs, as well as what the result of the comparison is:

`1.5 <= 2.0`
: numeric comparison (true)

`"abc" >= "xyz"`
: string comparison (false)

`1.5 != " +2"`
: string comparison (true)

`"1e2" < "3"`
: string comparison (true)

`a = 2; b = "2"`
`a == b` string comparison (true)

`a = 2; b = " +2"`
`a == b` string comparison (false)

In this example:

```
$ echo 1e2 3 | awk '{ print ($1 < $2) ? "true" : "false" }'
⊣ false
```

the result is 'false' because both $1 and $2 are user input. They are numeric strings—therefore both have the *strnum* attribute, dictating a numeric comparison. The purpose of the comparison rules and the use of numeric strings is to attempt to produce the behavior that is "least surprising," while still "doing the right thing."

String comparisons and regular expression comparisons are very different. For example:

```
x == "foo"
```

has the value one, or is true if the variable x is precisely 'foo'. By contrast:

```
x ~ /foo/
```

has the value one if x contains 'foo', such as "Oh, what a fool am I!".

The righthand operand of the '~' and '!~' operators may be either a regexp constant (/.../) or an ordinary expression. In the latter case, the value of the expression as a string is used as a dynamic regexp (see Section 3.1 [How to Use Regular Expressions], page 43; also see Section 3.8 [Using Dynamic Regexps], page 53).

In modern implementations of awk, a constant regular expression in slashes by itself is also an expression. The regexp */regexp/* is an abbreviation for the following comparison expression:

```
$0 ~ /regexp/
```

One special place where /foo/ is *not* an abbreviation for '$0 ~ /foo/' is when it is the righthand operand of '~' or '!~'. See Section 6.1.2 [Using Regular Expression Constants], page 99, where this is discussed in more detail.

6.3.2.3 String Comparison With POSIX Rules

The POSIX standard says that string comparison is performed based on the locale's collating order. This is usually very different from the results obtained when doing straight character-by-character comparison.[5]

Because this behavior differs considerably from existing practice, gawk only implements it when in POSIX mode (see Section 2.2 [Command-Line Options], page 29). Here is an example to illustrate the difference, in an 'en_US.UTF-8' locale:

```
$ gawk 'BEGIN { printf("ABC < abc = %s\n",
>                      ("ABC" < "abc" ? "TRUE" : "FALSE")) }'
⊣ ABC < abc = TRUE
$ gawk --posix 'BEGIN { printf("ABC < abc = %s\n",
>                              ("ABC" < "abc" ? "TRUE" : "FALSE")) }'
⊣ ABC < abc = FALSE
```

6.3.3 Boolean Expressions

A *Boolean expression* is a combination of comparison expressions or matching expressions, using the Boolean operators "or" ('||'), "and" ('&&'), and "not" ('!'), along with parentheses

[5] Technically, string comparison is supposed to behave the same way as if the strings are compared with the C strcoll() function.

to control nesting. The truth value of the Boolean expression is computed by combining the truth values of the component expressions. Boolean expressions are also referred to as *logical expressions*. The terms are equivalent.

Boolean expressions can be used wherever comparison and matching expressions can be used. They can be used in `if`, `while`, `do`, and `for` statements (see Section 7.4 [Control Statements in Actions], page 126). They have numeric values (one if true, zero if false) that come into play if the result of the Boolean expression is stored in a variable or used in arithmetic.

In addition, every Boolean expression is also a valid pattern, so you can use one as a pattern to control the execution of rules. The Boolean operators are:

`boolean1 && boolean2`
: True if both *boolean1* and *boolean2* are true. For example, the following statement prints the current input record if it contains both '2400' and 'foo':

```
if ($0 ~ /2400/ && $0 ~ /foo/) print
```

The subexpression *boolean2* is evaluated only if *boolean1* is true. This can make a difference when *boolean2* contains expressions that have side effects. In the case of '`$0 ~ /foo/ && ($2 == bar++)`', the variable `bar` is not incremented if there is no substring '`foo`' in the record.

`boolean1 || boolean2`
: True if at least one of *boolean1* or *boolean2* is true. For example, the following statement prints all records in the input that contain *either* '2400' or '`foo`' or both:

```
if ($0 ~ /2400/ || $0 ~ /foo/) print
```

The subexpression *boolean2* is evaluated only if *boolean1* is false. This can make a difference when *boolean2* contains expressions that have side effects.

`! boolean`
: True if *boolean* is false. For example, the following program prints '`no home!`' in the unusual event that the `HOME` environment variable is not defined:

```
BEGIN { if (! ("HOME" in ENVIRON))
                print "no home!" }
```

(The `in` operator is described in Section 8.1.2 [Referring to an Array Element], page 146.)

The '`&&`' and '`||`' operators are called *short-circuit* operators because of the way they work. Evaluation of the full expression is "short-circuited" if the result can be determined part way through its evaluation.

Statements that use '`&&`' or '`||`' can be continued simply by putting a newline after them. But you cannot put a newline in front of either of these operators without using backslash continuation (see Section 1.6 [`awk` Statements Versus Lines], page 25).

The actual value of an expression using the '`!`' operator is either one or zero, depending upon the truth value of the expression it is applied to. The '`!`' operator is often useful for changing the sense of a flag variable from false to true and back again. For example, the following program is one way to print lines in between special bracketing lines:

```
$1 == "START"   { interested = ! interested; next }
interested == 1 { print }
```

```
$1 == "END"     { interested = ! interested; next }
```

The variable `interested`, as with all `awk` variables, starts out initialized to zero, which is also false. When a line is seen whose first field is '`START`', the value of `interested` is toggled to true, using '`!`'. The next rule prints lines as long as `interested` is true. When a line is seen whose first field is '`END`', `interested` is toggled back to false.[6]

> **NOTE:** The `next` statement is discussed in Section 7.4.8 [The `next` Statement], page 132. `next` tells `awk` to skip the rest of the rules, get the next record, and start processing the rules over again at the top. The reason it's there is to avoid printing the bracketing '`START`' and '`END`' lines.

6.3.4 Conditional Expressions

A *conditional expression* is a special kind of expression that has three operands. It allows you to use one expression's value to select one of two other expressions. The conditional expression is the same as in the C language, as shown here:

```
selector ? if-true-exp : if-false-exp
```

There are three subexpressions. The first, *selector*, is always computed first. If it is "true" (not zero or not null), then *if-true-exp* is computed next and its value becomes the value of the whole expression. Otherwise, *if-false-exp* is computed next and its value becomes the value of the whole expression. For example, the following expression produces the absolute value of `x`:

```
x >= 0 ? x : -x
```

Each time the conditional expression is computed, only one of *if-true-exp* and *if-false-exp* is used; the other is ignored. This is important when the expressions have side effects. For example, this conditional expression examines element `i` of either array `a` or array `b`, and increments `i`:

```
x == y ? a[i++] : b[i++]
```

This is guaranteed to increment `i` exactly once, because each time only one of the two increment expressions is executed and the other is not. See Chapter 8 [Arrays in `awk`], page 145, for more information about arrays.

As a minor `gawk` extension, a statement that uses '`?:`' can be continued simply by putting a newline after either character. However, putting a newline in front of either character does not work without using backslash continuation (see Section 1.6 [`awk` Statements Versus Lines], page 25). If `--posix` is specified (see Section 2.2 [Command-Line Options], page 29), then this extension is disabled.

6.4 Function Calls

A *function* is a name for a particular calculation. This enables you to ask for it by name at any point in the program. For example, the function `sqrt()` computes the square root of a number.

A fixed set of functions are *built-in*, which means they are available in every `awk` program. The `sqrt()` function is one of these. See Section 9.1 [Built-in Functions], page 159, for a list of built-in functions and their descriptions. In addition, you can define functions for

[6] This program has a bug; it prints lines starting with '`END`'. How would you fix it?

use in your program. See Section 9.2 [User-Defined Functions], page 184, for instructions on how to do this.

The way to use a function is with a *function call* expression, which consists of the function name followed immediately by a list of *arguments* in parentheses. The arguments are expressions that provide the raw materials for the function's calculations. When there is more than one argument, they are separated by commas. If there are no arguments, just write '`()`' after the function name. The following examples show function calls with and without arguments:

```
sqrt(x^2 + y^2)        one argument
atan2(y, x)            two arguments
rand()                 no arguments
```

> **CAUTION:** Do not put any space between the function name and the open-parenthesis! A user-defined function name looks just like the name of a variable—a space would make the expression look like concatenation of a variable with an expression inside parentheses. With built-in functions, space before the parenthesis is harmless, but it is best not to get into the habit of using space to avoid mistakes with user-defined functions.

Each function expects a particular number of arguments. For example, the `sqrt()` function must be called with a single argument, the number of which to take the square root:

```
sqrt(argument)
```

Some of the built-in functions have one or more optional arguments. If those arguments are not supplied, the functions use a reasonable default value. See Section 9.1 [Built-in Functions], page 159, for full details. If arguments are omitted in calls to user-defined functions, then those arguments are treated as local variables and initialized to the empty string (see Section 9.2 [User-Defined Functions], page 184).

As an advanced feature, `gawk` provides indirect function calls, which is a way to choose the function to call at runtime, instead of when you write the source code to your program. We defer discussion of this feature until later; see Section 9.3 [Indirect Function Calls], page 193.

Like every other expression, the function call has a value, which is computed by the function based on the arguments you give it. In this example, the value of '`sqrt(argument)`' is the square root of *argument*. The following program reads numbers, one number per line, and prints the square root of each one:

```
$ awk '{ print "The square root of", $1, "is", sqrt($1) }'
1
⊣ The square root of 1 is 1
3
⊣ The square root of 3 is 1.73205
5
⊣ The square root of 5 is 2.23607
Ctrl-d
```

A function can also have side effects, such as assigning values to certain variables or doing I/O. This program shows how the `match()` function (see Section 9.1.3 [String-Manipulation Functions], page 161) changes the variables `RSTART` and `RLENGTH`:

```
{
    if (match($1, $2))
        print RSTART, RLENGTH
    else
        print "no match"
}
```

Here is a sample run:

```
$ awk -f matchit.awk
aaccdd  c+
⊣ 3 2
foo     bar
⊣ no match
abcdefg e
⊣ 5 1
```

6.5 Operator Precedence (How Operators Nest)

Operator precedence determines how operators are grouped when different operators appear close by in one expression. For example, '`*`' has higher precedence than '`+`'; thus, '`a + b * c`' means to multiply `b` and `c`, and then add `a` to the product (i.e., '`a + (b * c)`').

The normal precedence of the operators can be overruled by using parentheses. Think of the precedence rules as saying where the parentheses are assumed to be. In fact, it is wise to always use parentheses whenever there is an unusual combination of operators, because other people who read the program may not remember what the precedence is in this case. Even experienced programmers occasionally forget the exact rules, which leads to mistakes. Explicit parentheses help prevent any such mistakes.

When operators of equal precedence are used together, the leftmost operator groups first, except for the assignment, conditional, and exponentiation operators, which group in the opposite order. Thus, '`a - b + c`' groups as '`(a - b) + c`' and '`a = b = c`' groups as '`a = (b = c)`'.

Normally the precedence of prefix unary operators does not matter, because there is only one way to interpret them: innermost first. Thus, '`$++i`' means '`$(++i)`' and '`++$x`' means '`++($x)`'. However, when another operator follows the operand, then the precedence of the unary operators can matter. '`$x^2`' means '`($x)^2`', but '`-x^2`' means '`-(x^2)`', because '`-`' has lower precedence than '`^`', whereas '`$`' has higher precedence. Also, operators cannot be combined in a way that violates the precedence rules; for example, '`$$0++--`' is not a valid expression because the first '`$`' has higher precedence than the '`++`'; to avoid the problem the expression can be rewritten as '`$($0++)--`'.

This table presents `awk`'s operators, in order of highest to lowest precedence:

`(...)` Grouping.

`$` Field reference.

`++ --` Increment, decrement.

`^ **` Exponentiation. These operators group right-to-left.

`+ - !` Unary plus, minus, logical "not."

`* / %` Multiplication, division, remainder.

`+ -` Addition, subtraction.

String Concatenation
: There is no special symbol for concatenation. The operands are simply written side by side (see Section 6.2.2 [String Concatenation], page 104).

`< <= == != > >= >> | |&`
: Relational and redirection. The relational operators and the redirections have the same precedence level. Characters such as '`>`' serve both as relationals and as redirections; the context distinguishes between the two meanings.

  Note that the I/O redirection operators in `print` and `printf` statements belong to the statement level, not to expressions. The redirection does not produce an expression that could be the operand of another operator. As a result, it does not make sense to use a redirection operator near another operator of lower precedence without parentheses. Such combinations (for example, '`print foo > a ? b : c`'), result in syntax errors. The correct way to write this statement is '`print foo > (a ? b : c)`'.

`~ !~` Matching, nonmatching.

`in` Array membership.

`&&` Logical "and".

`||` Logical "or".

`?:` Conditional. This operator groups right-to-left.

`= += -= *= /= %= ^= **=`
: Assignment. These operators group right-to-left.

> **NOTE:** The '`|&`', '`**`', and '`**=`' operators are not specified by POSIX. For maximum portability, do not use them.

6.6 Where You Are Makes A Difference

Modern systems support the notion of *locales*: a way to tell the system about the local character set and language.

Once upon a time, the locale setting used to affect regexp matching (see Section A.7 [Regexp Ranges and Locales: A Long Sad Story], page 394), but this is no longer true.

Locales can affect record splitting. For the normal case of '`RS = "\n"`', the locale is largely irrelevant. For other single-character record separators, setting '`LC_ALL=C`' in the environment will give you much better performance when reading records. Otherwise, `gawk` has to make several function calls, *per input character*, to find the record terminator.

According to POSIX, string comparison is also affected by locales (similar to regular expressions). The details are presented in Section 6.3.2.3 [String Comparison With POSIX Rules], page 113.

Finally, the locale affects the value of the decimal point character used when `gawk` parses input data. This is discussed in detail in Section 6.1.4 [Conversion of Strings and Numbers], page 101.

7 Patterns, Actions, and Variables

As you have already seen, each `awk` statement consists of a pattern with an associated action. This chapter describes how you build patterns and actions, what kinds of things you can do within actions, and `awk`'s built-in variables.

The pattern-action rules and the statements available for use within actions form the core of `awk` programming. In a sense, everything covered up to here has been the foundation that programs are built on top of. Now it's time to start building something useful.

7.1 Pattern Elements

Patterns in `awk` control the execution of rules—a rule is executed when its pattern matches the current input record. The following is a summary of the types of `awk` patterns:

/regular expression/
: A regular expression. It matches when the text of the input record fits the regular expression. (See Chapter 3 [Regular Expressions], page 43.)

expression
: A single expression. It matches when its value is nonzero (if a number) or non-null (if a string). (See Section 7.1.2 [Expressions as Patterns], page 119.)

pat1, pat2
: A pair of patterns separated by a comma, specifying a range of records. The range includes both the initial record that matches *pat1* and the final record that matches *pat2*. (See Section 7.1.3 [Specifying Record Ranges with Patterns], page 121.)

`BEGIN`
`END`
: Special patterns for you to supply startup or cleanup actions for your `awk` program. (See Section 7.1.4 [The BEGIN and END Special Patterns], page 122.)

`BEGINFILE`
`ENDFILE`
: Special patterns for you to supply startup or cleanup actions to be done on a per file basis. (See Section 7.1.5 [The BEGINFILE and ENDFILE Special Patterns], page 123.)

empty
: The empty pattern matches every input record. (See Section 7.1.6 [The Empty Pattern], page 124.)

7.1.1 Regular Expressions as Patterns

Regular expressions are one of the first kinds of patterns presented in this book. This kind of pattern is simply a regexp constant in the pattern part of a rule. Its meaning is '`$0 ~ /pattern/`'. The pattern matches when the input record matches the regexp. For example:

```
/foo|bar|baz/  { buzzwords++ }
END            { print buzzwords, "buzzwords seen" }
```

7.1.2 Expressions as Patterns

Any `awk` expression is valid as an `awk` pattern. The pattern matches if the expression's value is nonzero (if a number) or non-null (if a string). The expression is reevaluated each time the rule is tested against a new input record. If the expression uses fields such as `$1`, the value depends directly on the new input record's text; otherwise, it depends on only what has happened so far in the execution of the `awk` program.

Comparison expressions, using the comparison operators described in Section 6.3.2 [Variable Typing and Comparison Expressions], page 110, are a very common kind of pattern. Regexp matching and nonmatching are also very common expressions. The left operand of the '`~`' and '`!~`' operators is a string. The right operand is either a constant regular expression enclosed in slashes (`/regexp/`), or any expression whose string value is used as a dynamic regular expression (see Section 3.8 [Using Dynamic Regexps], page 53). The following example prints the second field of each input record whose first field is precisely '`foo`':

```
$ awk '$1 == "foo" { print $2 }' BBS-list
```

(There is no output, because there is no BBS site with the exact name '`foo`'.) Contrast this with the following regular expression match, which accepts any record with a first field that contains '`foo`':

```
$ awk '$1 ~ /foo/ { print $2 }' BBS-list
⊣ 555-1234
⊣ 555-6699
⊣ 555-6480
⊣ 555-2127
```

A regexp constant as a pattern is also a special case of an expression pattern. The expression `/foo/` has the value one if '`foo`' appears in the current input record. Thus, as a pattern, `/foo/` matches any record containing '`foo`'.

Boolean expressions are also commonly used as patterns. Whether the pattern matches an input record depends on whether its subexpressions match. For example, the following command prints all the records in `BBS-list` that contain both '2400' and '`foo`':

```
$ awk '/2400/ && /foo/' BBS-list
⊣ fooey         555-1234      2400/1200/300     B
```

The following command prints all records in `BBS-list` that contain *either* '2400' or '`foo`' (or both, of course):

```
$ awk '/2400/ || /foo/' BBS-list
⊣ alpo-net      555-3412      2400/1200/300     A
⊣ bites         555-1675      2400/1200/300     A
⊣ fooey         555-1234      2400/1200/300     B
⊣ foot          555-6699      1200/300          B
⊣ macfoo        555-6480      1200/300          A
⊣ sdace         555-3430      2400/1200/300     A
⊣ sabafoo       555-2127      1200/300          C
```

The following command prints all records in `BBS-list` that do *not* contain the string '`foo`':

```
$ awk '! /foo/' BBS-list
⊣ aardvark      555-5553      1200/300          B
⊣ alpo-net      555-3412      2400/1200/300     A
⊣ barfly        555-7685      1200/300          A
```

```
⊣ bites        555-1675     2400/1200/300     A
⊣ camelot      555-0542     300               C
⊣ core         555-2912     1200/300          C
⊣ sdace        555-3430     2400/1200/300     A
```

The subexpressions of a Boolean operator in a pattern can be constant regular expressions, comparisons, or any other `awk` expressions. Range patterns are not expressions, so they cannot appear inside Boolean patterns. Likewise, the special patterns `BEGIN`, `END`, `BEGINFILE` and `ENDFILE`, which never match any input record, are not expressions and cannot appear inside Boolean patterns.

The precedence of the different operators which can appear in patterns is described in Section 6.5 [Operator Precedence (How Operators Nest)], page 117.

7.1.3 Specifying Record Ranges with Patterns

A *range pattern* is made of two patterns separated by a comma, in the form '*`begpat, endpat`*'. It is used to match ranges of consecutive input records. The first pattern, *begpat*, controls where the range begins, while *endpat* controls where the pattern ends. For example, the following:

```
awk '$1 == "on", $1 == "off"' myfile
```

prints every record in `myfile` between '`on`'/'`off`' pairs, inclusive.

A range pattern starts out by matching *begpat* against every input record. When a record matches *begpat*, the range pattern is *turned on* and the range pattern matches this record as well. As long as the range pattern stays turned on, it automatically matches every input record read. The range pattern also matches *endpat* against every input record; when this succeeds, the range pattern is turned off again for the following record. Then the range pattern goes back to checking *begpat* against each record.

The record that turns on the range pattern and the one that turns it off both match the range pattern. If you don't want to operate on these records, you can write `if` statements in the rule's action to distinguish them from the records you are interested in.

It is possible for a pattern to be turned on and off by the same record. If the record satisfies both conditions, then the action is executed for just that record. For example, suppose there is text between two identical markers (e.g., the '`%`' symbol), each on its own line, that should be ignored. A first attempt would be to combine a range pattern that describes the delimited text with the `next` statement (not discussed yet, see Section 7.4.8 [The `next` Statement], page 132). This causes `awk` to skip any further processing of the current record and start over again with the next input record. Such a program looks like this:

```
/^%$/,/^%$/    { next }
               { print }
```

This program fails because the range pattern is both turned on and turned off by the first line, which just has a '`%`' on it. To accomplish this task, write the program in the following manner, using a flag:

```
/^%$/     { skip = ! skip; next }
skip == 1 { next } # skip lines with 'skip' set
```

In a range pattern, the comma (‘,’) has the lowest precedence of all the operators (i.e., it is evaluated last). Thus, the following program attempts to combine a range pattern with another, simpler test:

```
echo Yes | awk '/1/,/2/ || /Yes/'
```

The intent of this program is ‘(/1/,/2/) || /Yes/’. However, awk interprets this as ‘/1/, (/2/ || /Yes/)’. This cannot be changed or worked around; range patterns do not combine with other patterns:

```
$ echo Yes | gawk '(/1/,/2/) || /Yes/'
error gawk: cmd. line:1: (/1/,/2/) || /Yes/
error gawk: cmd. line:1:           ^ syntax error
```

7.1.4 The BEGIN and END Special Patterns

All the patterns described so far are for matching input records. The BEGIN and END special patterns are different. They supply startup and cleanup actions for awk programs. BEGIN and END rules must have actions; there is no default action for these rules because there is no current record when they run. BEGIN and END rules are often referred to as “BEGIN and END blocks” by long-time awk programmers.

7.1.4.1 Startup and Cleanup Actions

A BEGIN rule is executed once only, before the first input record is read. Likewise, an END rule is executed once only, after all the input is read. For example:

```
$ awk '
> BEGIN { print "Analysis of \"foo\"" }
> /foo/ { ++n }
> END   { print "\"foo\" appears", n, "times." }' BBS-list
⊣ Analysis of "foo"
⊣ "foo" appears 4 times.
```

This program finds the number of records in the input file BBS-list that contain the string ‘foo’. The BEGIN rule prints a title for the report. There is no need to use the BEGIN rule to initialize the counter n to zero, since awk does this automatically (see Section 6.1.3 [Variables], page 100). The second rule increments the variable n every time a record containing the pattern ‘foo’ is read. The END rule prints the value of n at the end of the run.

The special patterns BEGIN and END cannot be used in ranges or with Boolean operators (indeed, they cannot be used with any operators). An awk program may have multiple BEGIN and/or END rules. They are executed in the order in which they appear: all the BEGIN rules at startup and all the END rules at termination. BEGIN and END rules may be intermixed with other rules. This feature was added in the 1987 version of awk and is included in the POSIX standard. The original (1978) version of awk required the BEGIN rule to be placed at the beginning of the program, the END rule to be placed at the end, and only allowed one of each. This is no longer required, but it is a good idea to follow this template in terms of program organization and readability.

Multiple BEGIN and END rules are useful for writing library functions, because each library file can have its own BEGIN and/or END rule to do its own initialization and/or cleanup. The order in which library functions are named on the command line controls the order in which their BEGIN and END rules are executed. Therefore, you have to be careful when writing such rules in library files so that the order in which they are executed doesn't matter. See Section 2.2 [Command-Line Options], page 29, for more information on using library functions. See Chapter 10 [A Library of awk Functions], page 201, for a number of useful library functions.

If an awk program has only BEGIN rules and no other rules, then the program exits after the BEGIN rule is run.[1] However, if an END rule exists, then the input is read, even if there are no other rules in the program. This is necessary in case the END rule checks the FNR and NR variables.

7.1.4.2 Input/Output from BEGIN and END Rules

There are several (sometimes subtle) points to remember when doing I/O from a BEGIN or END rule. The first has to do with the value of $0 in a BEGIN rule. Because BEGIN rules are executed before any input is read, there simply is no input record, and therefore no fields, when executing BEGIN rules. References to $0 and the fields yield a null string or zero, depending upon the context. One way to give $0 a real value is to execute a getline command without a variable (see Section 4.9 [Explicit Input with getline], page 73). Another way is simply to assign a value to $0.

The second point is similar to the first but from the other direction. Traditionally, due largely to implementation issues, $0 and NF were *undefined* inside an END rule. The POSIX standard specifies that NF is available in an END rule. It contains the number of fields from the last input record. Most probably due to an oversight, the standard does not say that $0 is also preserved, although logically one would think that it should be. In fact, gawk does preserve the value of $0 for use in END rules. Be aware, however, that Brian Kernighan's awk, and possibly other implementations, do not.

The third point follows from the first two. The meaning of 'print' inside a BEGIN or END rule is the same as always: 'print $0'. If $0 is the null string, then this prints an empty record. Many long time awk programmers use an unadorned 'print' in BEGIN and END rules, to mean 'print ""', relying on $0 being null. Although one might generally get away with this in BEGIN rules, it is a very bad idea in END rules, at least in gawk. It is also poor style, since if an empty line is needed in the output, the program should print one explicitly.

Finally, the next and nextfile statements are not allowed in a BEGIN rule, because the implicit read-a-record-and-match-against-the-rules loop has not started yet. Similarly, those statements are not valid in an END rule, since all the input has been read. (See Section 7.4.8 [The next Statement], page 132, and see Section 7.4.9 [The nextfile Statement], page 133.)

7.1.5 The BEGINFILE and ENDFILE Special Patterns

This section describes a gawk-specific feature.

Two special kinds of rule, BEGINFILE and ENDFILE, give you "hooks" into gawk's command-line file processing loop. As with the BEGIN and END rules (see Section 7.1.4 [The BEGIN and END Special Patterns], page 122), all BEGINFILE rules in a program are merged, in the order they are read by gawk, and all ENDFILE rules are merged as well.

[1] The original version of awk kept reading and ignoring input until the end of the file was seen.

The body of the BEGINFILE rules is executed just before gawk reads the first record from a file. FILENAME is set to the name of the current file, and FNR is set to zero.

The BEGINFILE rule provides you the opportunity to accomplish two tasks that would otherwise be difficult or impossible to perform:

- You can test if the file is readable. Normally, it is a fatal error if a file named on the command line cannot be opened for reading. However, you can bypass the fatal error and move on to the next file on the command line.

  You do this by checking if the ERRNO variable is not the empty string; if so, then gawk was not able to open the file. In this case, your program can execute the nextfile statement (see Section 7.4.9 [The nextfile Statement], page 133). This causes gawk to skip the file entirely. Otherwise, gawk exits with the usual fatal error.
- If you have written extensions that modify the record handling (by inserting an "input parser"), you can invoke them at this point, before gawk has started processing the file. (This is a *very* advanced feature, currently used only by the gawkextlib project (http://gawkextlib.sourceforge.net).)

The ENDFILE rule is called when gawk has finished processing the last record in an input file. For the last input file, it will be called before any END rules. The ENDFILE rule is executed even for empty input files.

Normally, when an error occurs when reading input in the normal input processing loop, the error is fatal. However, if an ENDFILE rule is present, the error becomes non-fatal, and instead ERRNO is set. This makes it possible to catch and process I/O errors at the level of the awk program.

The next statement (see Section 7.4.8 [The next Statement], page 132) is not allowed inside either a BEGINFILE or and ENDFILE rule. The nextfile statement (see Section 7.4.9 [The nextfile Statement], page 133) is allowed only inside a BEGINFILE rule, but not inside an ENDFILE rule.

The getline statement (see Section 4.9 [Explicit Input with getline], page 73) is restricted inside both BEGINFILE and ENDFILE. Only the 'getline *variable* < *file*' form is allowed.

BEGINFILE and ENDFILE are gawk extensions. In most other awk implementations, or if gawk is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), they are not special.

7.1.6 The Empty Pattern

An empty (i.e., nonexistent) pattern is considered to match *every* input record. For example, the program:

```
awk '{ print $1 }' BBS-list
```

prints the first field of every record.

7.2 Using Shell Variables in Programs

awk programs are often used as components in larger programs written in shell. For example, it is very common to use a shell variable to hold a pattern that the awk program searches for. There are two ways to get the value of the shell variable into the body of the awk program.

The most common method is to use shell quoting to substitute the variable's value into the program inside the script. For example, in the following program:

```
printf "Enter search pattern: "
read pattern
awk "/$pattern/ "'{ nmatches++ }
     END { print nmatches, "found" }' /path/to/data
```

the awk program consists of two pieces of quoted text that are concatenated together to form the program. The first part is double-quoted, which allows substitution of the pattern shell variable inside the quotes. The second part is single-quoted.

Variable substitution via quoting works, but can be potentially messy. It requires a good understanding of the shell's quoting rules (see Section 1.1.6 [Shell-Quoting Issues], page 19), and it's often difficult to correctly match up the quotes when reading the program.

A better method is to use awk's variable assignment feature (see Section 6.1.3.2 [Assigning Variables on the Command Line], page 100) to assign the shell variable's value to an awk variable's value. Then use dynamic regexps to match the pattern (see Section 3.8 [Using Dynamic Regexps], page 53). The following shows how to redo the previous example using this technique:

```
printf "Enter search pattern: "
read pattern
awk -v pat="$pattern" '$0 ~ pat { nmatches++ }
       END { print nmatches, "found" }' /path/to/data
```

Now, the awk program is just one single-quoted string. The assignment '-v pat="$pattern"' still requires double quotes, in case there is whitespace in the value of $pattern. The awk variable pat could be named pattern too, but that would be more confusing. Using a variable also provides more flexibility, since the variable can be used anywhere inside the program—for printing, as an array subscript, or for any other use—without requiring the quoting tricks at every point in the program.

7.3 Actions

An awk program or script consists of a series of rules and function definitions interspersed. (Functions are described later. See Section 9.2 [User-Defined Functions], page 184.) A rule contains a pattern and an action, either of which (but not both) may be omitted. The purpose of the *action* is to tell awk what to do once a match for the pattern is found. Thus, in outline, an awk program generally looks like this:

```
[pattern]  { action }
 pattern  [{ action }]
...
function name(args) { ... }
...
```

An action consists of one or more awk *statements*, enclosed in curly braces ('{...}'). Each statement specifies one thing to do. The statements are separated by newlines or semicolons. The curly braces around an action must be used even if the action contains only one statement, or if it contains no statements at all. However, if you omit the action entirely, omit the curly braces as well. An omitted action is equivalent to '{ print $0 }':

```
/foo/  { }     match foo, do nothing — empty action
/foo/          match foo, print the record — omitted action
```

The following types of statements are supported in `awk`:

Expressions
: Call functions or assign values to variables (see Chapter 6 [Expressions], page 97). Executing this kind of statement simply computes the value of the expression. This is useful when the expression has side effects (see Section 6.2.3 [Assignment Expressions], page 106).

Control statements
: Specify the control flow of `awk` programs. The `awk` language gives you C-like constructs (`if`, `for`, `while`, and `do`) as well as a few special ones (see Section 7.4 [Control Statements in Actions], page 126).

Compound statements
: Consist of one or more statements enclosed in curly braces. A compound statement is used in order to put several statements together in the body of an `if`, `while`, `do`, or `for` statement.

Input statements
: Use the `getline` command (see Section 4.9 [Explicit Input with `getline`], page 73). Also supplied in `awk` are the `next` statement (see Section 7.4.8 [The `next` Statement], page 132), and the `nextfile` statement (see Section 7.4.9 [The `nextfile` Statement], page 133).

Output statements
: Such as `print` and `printf`. See Chapter 5 [Printing Output], page 81.

Deletion statements
: For deleting array elements. See Section 8.2 [The `delete` Statement], page 151.

7.4 Control Statements in Actions

Control statements, such as `if`, `while`, and so on, control the flow of execution in `awk` programs. Most of `awk`'s control statements are patterned after similar statements in C.

All the control statements start with special keywords, such as `if` and `while`, to distinguish them from simple expressions. Many control statements contain other statements. For example, the `if` statement contains another statement that may or may not be executed. The contained statement is called the *body*. To include more than one statement in the body, group them into a single *compound statement* with curly braces, separating them with newlines or semicolons.

7.4.1 The `if-else` Statement

The `if-else` statement is `awk`'s decision-making statement. It looks like this:

```
if (condition) then-body [else else-body]
```

The *condition* is an expression that controls what the rest of the statement does. If the *condition* is true, *then-body* is executed; otherwise, *else-body* is executed. The `else` part of the statement is optional. The condition is considered false if its value is zero or the null string; otherwise, the condition is true. Refer to the following:

```
if (x % 2 == 0)
    print "x is even"
else
    print "x is odd"
```

In this example, if the expression '`x % 2 == 0`' is true (that is, if the value of `x` is evenly divisible by two), then the first `print` statement is executed; otherwise, the second `print` statement is executed. If the `else` keyword appears on the same line as *then-body* and *then-body* is not a compound statement (i.e., not surrounded by curly braces), then a semicolon must separate *then-body* from the `else`. To illustrate this, the previous example can be rewritten as:

```
if (x % 2 == 0) print "x is even"; else
        print "x is odd"
```

If the '`;`' is left out, `awk` can't interpret the statement and it produces a syntax error. Don't actually write programs this way, because a human reader might fail to see the `else` if it is not the first thing on its line.

7.4.2 The `while` Statement

In programming, a *loop* is a part of a program that can be executed two or more times in succession. The `while` statement is the simplest looping statement in `awk`. It repeatedly executes a statement as long as a condition is true. For example:

```
while (condition)
  body
```

body is a statement called the *body* of the loop, and *condition* is an expression that controls how long the loop keeps running. The first thing the `while` statement does is test the *condition*. If the *condition* is true, it executes the statement *body*. After *body* has been executed, *condition* is tested again, and if it is still true, *body* is executed again. This process repeats until the *condition* is no longer true. If the *condition* is initially false, the body of the loop is never executed and `awk` continues with the statement following the loop. This example prints the first three fields of each record, one per line:

```
awk '{
       i = 1
       while (i <= 3) {
           print $i
           i++
       }
}' inventory-shipped
```

The body of this loop is a compound statement enclosed in braces, containing two statements. The loop works in the following manner: first, the value of `i` is set to one. Then, the `while` statement tests whether `i` is less than or equal to three. This is true when `i` equals one, so the `i`-th field is printed. Then the '`i++`' increments the value of `i` and the loop repeats. The loop terminates when `i` reaches four.

A newline is not required between the condition and the body; however using one makes the program clearer unless the body is a compound statement or else is very simple. The newline after the open-brace that begins the compound statement is not required either, but the program is harder to read without it.

7.4.3 The do-while Statement

The `do` loop is a variation of the `while` looping statement. The `do` loop executes the *body* once and then repeats the *body* as long as the *condition* is true. It looks like this:

```
do
  body
while (condition)
```

Even if the *condition* is false at the start, the *body* is executed at least once (and only once, unless executing *body* makes *condition* true). Contrast this with the corresponding `while` statement:

```
while (condition)
  body
```

This statement does not execute *body* even once if the *condition* is false to begin with. The following is an example of a `do` statement:

```
{
       i = 1
       do {
          print $0
          i++
       } while (i <= 10)
}
```

This program prints each input record 10 times. However, it isn't a very realistic example, since in this case an ordinary `while` would do just as well. This situation reflects actual experience; only occasionally is there a real use for a `do` statement.

7.4.4 The for Statement

The `for` statement makes it more convenient to count iterations of a loop. The general form of the `for` statement looks like this:

```
for (initialization; condition; increment)
  body
```

The *initialization*, *condition*, and *increment* parts are arbitrary `awk` expressions, and *body* stands for any `awk` statement.

The `for` statement starts by executing *initialization*. Then, as long as the *condition* is true, it repeatedly executes *body* and then *increment*. Typically, *initialization* sets a variable to either zero or one, *increment* adds one to it, and *condition* compares it against the desired number of iterations. For example:

```
awk '{
       for (i = 1; i <= 3; i++)
          print $i
}' inventory-shipped
```

This prints the first three fields of each input record, with one field per line.

It isn't possible to set more than one variable in the *initialization* part without using a multiple assignment statement such as '`x = y = 0`'. This makes sense only if all the initial values are equal. (But it is possible to initialize additional variables by writing their assignments as separate statements preceding the `for` loop.)

The same is true of the *increment* part. Incrementing additional variables requires separate statements at the end of the loop. The C compound expression, using C's comma operator, is useful in this context but it is not supported in `awk`.

Most often, *increment* is an increment expression, as in the previous example. But this is not required; it can be any expression whatsoever. For example, the following statement prints all the powers of two between 1 and 100:

```
for (i = 1; i <= 100; i *= 2)
  print i
```

If there is nothing to be done, any of the three expressions in the parentheses following the `for` keyword may be omitted. Thus, '`for (; x > 0;)`' is equivalent to '`while (x > 0)`'. If the *condition* is omitted, it is treated as true, effectively yielding an *infinite loop* (i.e., a loop that never terminates).

In most cases, a `for` loop is an abbreviation for a `while` loop, as shown here:

```
initialization
while (condition) {
  body
  increment
}
```

The only exception is when the `continue` statement (see Section 7.4.7 [The `continue` Statement], page 131) is used inside the loop. Changing a `for` statement to a `while` statement in this way can change the effect of the `continue` statement inside the loop.

The `awk` language has a `for` statement in addition to a `while` statement because a `for` loop is often both less work to type and more natural to think of. Counting the number of iterations is very common in loops. It can be easier to think of this counting as part of looping rather than as something to do inside the loop.

There is an alternate version of the `for` loop, for iterating over all the indices of an array:

```
for (i in array)
    do something with array[i]
```

See Section 8.1.5 [Scanning All Elements of an Array], page 148, for more information on this version of the `for` loop.

7.4.5 The `switch` Statement

The `switch` statement allows the evaluation of an expression and the execution of statements based on a `case` match. Case statements are checked for a match in the order they are defined. If no suitable `case` is found, the `default` section is executed, if supplied.

Each `case` contains a single constant, be it numeric, string, or regexp. The `switch` expression is evaluated, and then each `case`'s constant is compared against the result in turn. The type of constant determines the comparison: numeric or string do the usual comparisons. A regexp constant does a regular expression match against the string value of the original expression. The general form of the `switch` statement looks like this:

```
switch (expression) {
case value or regular expression:
    case-body
default:
```

```
        default-body
    }
```

Control flow in the `switch` statement works as it does in C. Once a match to a given case is made, the case statement bodies execute until a `break`, `continue`, `next`, `nextfile` or `exit` is encountered, or the end of the `switch` statement itself. For example:

```
switch (NR * 2 + 1) {
case 3:
case "11":
    print NR - 1
    break

case /2[[:digit:]]+/:
    print NR

default:
    print NR + 1

case -1:
    print NR * -1
}
```

Note that if none of the statements specified above halt execution of a matched `case` statement, execution falls through to the next `case` until execution halts. In the above example, for any case value starting with '2' followed by one or more digits, the `print` statement is executed and then falls through into the `default` section, executing its `print` statement. In turn, the −1 case will also be executed since the `default` does not halt execution.

This `switch` statement is a `gawk` extension. If `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not available.

7.4.6 The `break` Statement

The `break` statement jumps out of the innermost `for`, `while`, or `do` loop that encloses it. The following example finds the smallest divisor of any integer, and also identifies prime numbers:

```
# find smallest divisor of num
{
   num = $1
   for (div = 2; div * div <= num; div++) {
     if (num % div == 0)
       break
   }
   if (num % div == 0)
     printf "Smallest divisor of %d is %d\n", num, div
   else
     printf "%d is prime\n", num
}
```

When the remainder is zero in the first `if` statement, `awk` immediately *breaks out* of the containing `for` loop. This means that `awk` proceeds immediately to the statement following the loop and continues processing. (This is very different from the `exit` statement, which stops the entire `awk` program. See Section 7.4.10 [The `exit` Statement], page 134.)

The following program illustrates how the *condition* of a `for` or `while` statement could be replaced with a `break` inside an `if`:

```
# find smallest divisor of num
{
  num = $1
  for (div = 2; ; div++) {
    if (num % div == 0) {
      printf "Smallest divisor of %d is %d\n", num, div
      break
    }
    if (div * div > num) {
      printf "%d is prime\n", num
      break
    }
  }
}
```

The `break` statement is also used to break out of the `switch` statement. This is discussed in Section 7.4.5 [The `switch` Statement], page 129.

The `break` statement has no meaning when used outside the body of a loop or `switch`. However, although it was never documented, historical implementations of `awk` treated the `break` statement outside of a loop as if it were a `next` statement (see Section 7.4.8 [The `next` Statement], page 132). Recent versions of Brian Kernighan's `awk` no longer allow this usage, nor does `gawk`.

7.4.7 The `continue` Statement

Similar to `break`, the `continue` statement is used only inside `for`, `while`, and `do` loops. It skips over the rest of the loop body, causing the next cycle around the loop to begin immediately. Contrast this with `break`, which jumps out of the loop altogether.

The `continue` statement in a `for` loop directs `awk` to skip the rest of the body of the loop and resume execution with the increment-expression of the `for` statement. The following program illustrates this fact:

```
BEGIN {
     for (x = 0; x <= 20; x++) {
         if (x == 5)
             continue
         printf "%d ", x
     }
     print ""
}
```

This program prints all the numbers from 0 to 20—except for 5, for which the `printf` is skipped. Because the increment '`x++`' is not skipped, `x` does not remain stuck at 5. Contrast the `for` loop from the previous example with the following `while` loop:

```
BEGIN {
     x = 0
     while (x <= 20) {
         if (x == 5)
             continue
         printf "%d ", x
         x++
     }
     print ""
}
```

This program loops forever once `x` reaches 5.

The `continue` statement has no special meaning with respect to the `switch` statement, nor does it have any meaning when used outside the body of a loop. Historical versions of `awk` treated a `continue` statement outside a loop the same way they treated a `break` statement outside a loop: as if it were a `next` statement (see Section 7.4.8 [The `next` Statement], page 132). Recent versions of Brian Kernighan's `awk` no longer work this way, nor does `gawk`.

7.4.8 The `next` Statement

The `next` statement forces `awk` to immediately stop processing the current record and go on to the next record. This means that no further rules are executed for the current record, and the rest of the current rule's action isn't executed.

Contrast this with the effect of the `getline` function (see Section 4.9 [Explicit Input with `getline`], page 73). That also causes `awk` to read the next record immediately, but it does not alter the flow of control in any way (i.e., the rest of the current action executes with a new input record).

At the highest level, `awk` program execution is a loop that reads an input record and then tests each rule's pattern against it. If you think of this loop as a `for` statement whose body contains the rules, then the `next` statement is analogous to a `continue` statement. It skips to the end of the body of this implicit loop and executes the increment (which reads another record).

For example, suppose an `awk` program works only on records with four fields, and it shouldn't fail when given bad input. To avoid complicating the rest of the program, write a "weed out" rule near the beginning, in the following manner:

```
NF != 4 {
  err = sprintf("%s:%d: skipped: NF != 4\n", FILENAME, FNR)
  print err > "/dev/stderr"
  next
}
```

Because of the `next` statement, the program's subsequent rules won't see the bad record. The error message is redirected to the standard error output stream, as error messages should be. For more detail see Section 5.7 [Special File Names in `gawk`], page 92.

If the `next` statement causes the end of the input to be reached, then the code in any `END` rules is executed. See Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122.

The `next` statement is not allowed inside `BEGINFILE` and `ENDFILE` rules. See Section 7.1.5 [The `BEGINFILE` and `ENDFILE` Special Patterns], page 123.

According to the POSIX standard, the behavior is undefined if the `next` statement is used in a `BEGIN` or `END` rule. `gawk` treats it as a syntax error. Although POSIX permits it, some other `awk` implementations don't allow the `next` statement inside function bodies (see Section 9.2 [User-Defined Functions], page 184). Just as with any other `next` statement, a `next` statement inside a function body reads the next record and starts processing it with the first rule in the program.

7.4.9 The `nextfile` Statement

The `nextfile` statement is similar to the `next` statement. However, instead of abandoning processing of the current record, the `nextfile` statement instructs `awk` to stop processing the current data file.

Upon execution of the `nextfile` statement, `FILENAME` is updated to the name of the next data file listed on the command line, `FNR` is reset to one, and processing starts over with the first rule in the program. If the `nextfile` statement causes the end of the input to be reached, then the code in any `END` rules is executed. An exception to this is when `nextfile` is invoked during execution of any statement in an `END` rule; In this case, it causes the program to stop immediately. See Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122.

The `nextfile` statement is useful when there are many data files to process but it isn't necessary to process every record in every file. Without `nextfile`, in order to move on to the next data file, a program would have to continue scanning the unwanted records. The `nextfile` statement accomplishes this much more efficiently.

In `gawk`, execution of `nextfile` causes additional things to happen: any `ENDFILE` rules are executed except in the case as mentioned below, `ARGIND` is incremented, and any `BEGINFILE` rules are executed. (`ARGIND` hasn't been introduced yet. See Section 7.5 [Built-in Variables], page 134.)

With `gawk`, `nextfile` is useful inside a `BEGINFILE` rule to skip over a file that would otherwise cause `gawk` to exit with a fatal error. In this case, `ENDFILE` rules are not executed. See Section 7.1.5 [The `BEGINFILE` and `ENDFILE` Special Patterns], page 123.

While one might think that '`close(FILENAME)`' would accomplish the same as `nextfile`, this isn't true. `close()` is reserved for closing files, pipes, and coprocesses that are opened with redirections. It is not related to the main processing that `awk` does with the files listed in `ARGV`.

> **NOTE:** For many years, `nextfile` was a `gawk` extension. As of September, 2012, it was accepted for inclusion into the POSIX standard. See the Austin Group website (`http://austingroupbugs.net/view.php?id=607`).

The current version of the Brian Kernighan's `awk` (see Section B.5 [Other Freely Available `awk` Implementations], page 412) also supports `nextfile`. However, it doesn't allow the `nextfile` statement inside function bodies (see Section 9.2 [User-Defined Functions], page 184). `gawk` does; a `nextfile` inside a function body reads the next record and starts processing it with the first rule in the program, just as any other `nextfile` statement.

7.4.10 The `exit` Statement

The `exit` statement causes `awk` to immediately stop executing the current rule and to stop processing input; any remaining input is ignored. The `exit` statement is written as follows:

`exit` [*return code*]

When an `exit` statement is executed from a `BEGIN` rule, the program stops processing everything immediately. No input records are read. However, if an `END` rule is present, as part of executing the `exit` statement, the `END` rule is executed (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122). If `exit` is used in the body of an `END` rule, it causes the program to stop immediately.

An `exit` statement that is not part of a `BEGIN` or `END` rule stops the execution of any further automatic rules for the current record, skips reading any remaining input records, and executes the `END` rule if there is one. Any `ENDFILE` rules are also skipped; they are not executed.

In such a case, if you don't want the `END` rule to do its job, set a variable to nonzero before the `exit` statement and check that variable in the `END` rule. See Section 10.2.2 [Assertions], page 204, for an example that does this.

If an argument is supplied to `exit`, its value is used as the exit status code for the `awk` process. If no argument is supplied, `exit` causes `awk` to return a "success" status. In the case where an argument is supplied to a first `exit` statement, and then `exit` is called a second time from an `END` rule with no argument, `awk` uses the previously supplied exit value. See Section 2.6 [`gawk`'s Exit Status], page 38, for more information.

For example, suppose an error condition occurs that is difficult or impossible to handle. Conventionally, programs report this by exiting with a nonzero status. An `awk` program can do this using an `exit` statement with a nonzero argument, as shown in the following example:

```
BEGIN {
       if (("date" | getline date_now) <= 0) {
         print "Can't get system date" > "/dev/stderr"
         exit 1
       }
       print "current date is", date_now
       close("date")
}
```

NOTE: For full portability, exit values should be between zero and 126, inclusive. Negative values, and values of 127 or greater, may not produce consistent results across different operating systems.

7.5 Built-in Variables

Most `awk` variables are available to use for your own purposes; they never change unless your program assigns values to them, and they never affect anything unless your program examines them. However, a few variables in `awk` have special built-in meanings. `awk` examines some of these automatically, so that they enable you to tell `awk` how to do certain things. Others are set automatically by `awk`, so that they carry information from the internal workings of `awk` to your program.

This section documents all the built-in variables of gawk, most of which are also documented in the chapters describing their areas of activity.

7.5.1 Built-in Variables That Control awk

The following is an alphabetical list of variables that you can change to control how awk does certain things. The variables that are specific to gawk are marked with a pound sign ('#').

BINMODE #
: On non-POSIX systems, this variable specifies use of binary mode for all I/O. Numeric values of one, two, or three specify that input files, output files, or all files, respectively, should use binary I/O. A numeric value less than zero is treated as zero, and a numeric value greater than three is treated as three. Alternatively, string values of "r" or "w" specify that input files and output files, respectively, should use binary I/O. A string value of "rw" or "wr" indicates that all files should use binary I/O. Any other string value is treated the same as "rw", but causes gawk to generate a warning message. BINMODE is described in more detail in Section B.3.1.4 [Using gawk on PC Operating Systems], page 407.

  This variable is a gawk extension. In other awk implementations (except mawk, see Section B.5 [Other Freely Available awk Implementations], page 412), or if gawk is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not special.

CONVFMT
: This string controls conversion of numbers to strings (see Section 6.1.4 [Conversion of Strings and Numbers], page 101). It works by being passed, in effect, as the first argument to the sprintf() function (see Section 9.1.3 [String-Manipulation Functions], page 161). Its default value is "%.6g". CONVFMT was introduced by the POSIX standard.

FIELDWIDTHS #
: This is a space-separated list of columns that tells gawk how to split input with fixed columnar boundaries. Assigning a value to FIELDWIDTHS overrides the use of FS and FPAT for field splitting. See Section 4.6 [Reading Fixed-Width Data], page 67, for more information.

  If gawk is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), then FIELDWIDTHS has no special meaning, and field-splitting operations occur based exclusively on the value of FS.

FPAT #
: This is a regular expression (as a string) that tells gawk to create the fields based on text that matches the regular expression. Assigning a value to FPAT overrides the use of FS and FIELDWIDTHS for field splitting. See Section 4.7 [Defining Fields By Content], page 69, for more information.

  If gawk is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), then FPAT has no special meaning, and field-splitting operations occur based exclusively on the value of FS.

FS
: This is the input field separator (see Section 4.5 [Specifying How Fields Are Separated], page 62). The value is a single-character string or a multicharacter regular expression that matches the separations between fields in an input record. If the value is the null string (""), then each character in the record becomes a separate field. (This behavior is a gawk extension. POSIX awk does

not specify the behavior when FS is the null string. Nonetheless, some other versions of awk also treat "" specially.)

The default value is " ", a string consisting of a single space. As a special exception, this value means that any sequence of spaces, TABs, and/or newlines is a single separator.[2] It also causes spaces, TABs, and newlines at the beginning and end of a record to be ignored.

You can set the value of FS on the command line using the -F option:

```
awk -F, 'program' input-files
```

If gawk is using FIELDWIDTHS or FPAT for field splitting, assigning a value to FS causes gawk to return to the normal, FS-based field splitting. An easy way to do this is to simply say 'FS = FS', perhaps with an explanatory comment.

IGNORECASE #
: If IGNORECASE is nonzero or non-null, then all string comparisons and all regular expression matching are case independent. Thus, regexp matching with '~' and '!~', as well as the gensub(), gsub(), index(), match(), patsplit(), split(), and sub() functions, record termination with RS, and field splitting with FS and FPAT, all ignore case when doing their particular regexp operations. However, the value of IGNORECASE does *not* affect array subscripting and it does not affect field splitting when using a single-character field separator. See Section 3.6 [Case Sensitivity in Matching], page 51.

If gawk is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), then IGNORECASE has no special meaning. Thus, string and regexp operations are always case-sensitive.

LINT #
: When this variable is true (nonzero or non-null), gawk behaves as if the --lint command-line option is in effect. (see Section 2.2 [Command-Line Options], page 29). With a value of "fatal", lint warnings become fatal errors. With a value of "invalid", only warnings about things that are actually invalid are issued. (This is not fully implemented yet.) Any other true value prints nonfatal warnings. Assigning a false value to LINT turns off the lint warnings.

This variable is a gawk extension. It is not special in other awk implementations. Unlike the other special variables, changing LINT does affect the production of lint warnings, even if gawk is in compatibility mode. Much as the --lint and --traditional options independently control different aspects of gawk's behavior, the control of lint warnings during program execution is independent of the flavor of awk being executed.

OFMT
: This string controls conversion of numbers to strings (see Section 6.1.4 [Conversion of Strings and Numbers], page 101) for printing with the print statement. It works by being passed as the first argument to the sprintf() function (see Section 9.1.3 [String-Manipulation Functions], page 161). Its default value is "%.6g". Earlier versions of awk also used OFMT to specify the format for converting numbers to strings in general expressions; this is now done by CONVFMT.

[2] In POSIX awk, newline does not count as whitespace.

`OFS` This is the output field separator (see Section 5.3 [Output Separators], page 83). It is output between the fields printed by a `print` statement. Its default value is `" "`, a string consisting of a single space.

`ORS` This is the output record separator. It is output at the end of every `print` statement. Its default value is `"\n"`, the newline character. (See Section 5.3 [Output Separators], page 83.)

`PREC #` The working precision of arbitrary precision floating-point numbers, 53 bits by default (see Section 15.4.1 [Setting the Working Precision], page 327).

`ROUNDMODE #`
The rounding mode to use for arbitrary precision arithmetic on numbers, by default `"N"` (‘`roundTiesToEven`’ in the IEEE-754 standard) (see Section 15.4.2 [Setting the Rounding Mode], page 328).

`RS` This is `awk`’s input record separator. Its default value is a string containing a single newline character, which means that an input record consists of a single line of text. It can also be the null string, in which case records are separated by runs of blank lines. If it is a regexp, records are separated by matches of the regexp in the input text. (See Section 4.1 [How Input Is Split into Records], page 55.)

The ability for `RS` to be a regular expression is a `gawk` extension. In most other `awk` implementations, or if `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), just the first character of `RS`’s value is used.

`SUBSEP` This is the subscript separator. It has the default value of `"\034"` and is used to separate the parts of the indices of a multidimensional array. Thus, the expression `foo["A", "B"]` really accesses `foo["A\034B"]` (see Section 8.5 [Multidimensional Arrays], page 154).

`TEXTDOMAIN #`
This variable is used for internationalization of programs at the `awk` level. It sets the default text domain for specially marked string constants in the source text, as well as for the `dcgettext()`, `dcngettext()` and `bindtextdomain()` functions (see Chapter 13 [Internationalization with `gawk`], page 291). The default value of `TEXTDOMAIN` is `"messages"`.

This variable is a `gawk` extension. In other `awk` implementations, or if `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not special.

7.5.2 Built-in Variables That Convey Information

The following is an alphabetical list of variables that `awk` sets automatically on certain occasions in order to provide information to your program. The variables that are specific to `gawk` are marked with a pound sign (‘`#`’).

`ARGC`, `ARGV`
The command-line arguments available to `awk` programs are stored in an array called `ARGV`. `ARGC` is the number of command-line arguments present. See Section 2.3 [Other Command-Line Arguments], page 35. Unlike most `awk` arrays, `ARGV` is indexed from 0 to `ARGC` − 1. In the following example:

```
$ awk 'BEGIN {
>         for (i = 0; i < ARGC; i++)
>             print ARGV[i]
>      }' inventory-shipped BBS-list
⊣ awk
⊣ inventory-shipped
⊣ BBS-list
```

ARGV[0] contains 'awk', ARGV[1] contains 'inventory-shipped', and ARGV[2] contains 'BBS-list'. The value of ARGC is three, one more than the index of the last element in ARGV, because the elements are numbered from zero.

The names ARGC and ARGV, as well as the convention of indexing the array from 0 to ARGC − 1, are derived from the C language's method of accessing command-line arguments.

The value of ARGV[0] can vary from system to system. Also, you should note that the program text is *not* included in ARGV, nor are any of awk's command-line options. See Section 7.5.3 [Using ARGC and ARGV], page 143, for information about how awk uses these variables.

ARGIND #
: The index in ARGV of the current file being processed. Every time gawk opens a new data file for processing, it sets ARGIND to the index in ARGV of the file name. When gawk is processing the input files, 'FILENAME == ARGV[ARGIND]' is always true.

This variable is useful in file processing; it allows you to tell how far along you are in the list of data files as well as to distinguish between successive instances of the same file name on the command line.

While you can change the value of ARGIND within your awk program, gawk automatically sets it to a new value when the next file is opened.

This variable is a gawk extension. In other awk implementations, or if gawk is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not special.

ENVIRON
: An associative array containing the values of the environment. The array indices are the environment variable names; the elements are the values of the particular environment variables. For example, ENVIRON["HOME"] might be /home/arnold. Changing this array does not affect the environment passed on to any programs that awk may spawn via redirection or the system() function.

Some operating systems may not have environment variables. On such systems, the ENVIRON array is empty (except for ENVIRON["AWKPATH"], see Section 2.5.1 [The AWKPATH Environment Variable], page 36 and ENVIRON["AWKLIBPATH"], see Section 2.5.2 [The AWKLIBPATH Environment Variable], page 37).

ERRNO #
: If a system error occurs during a redirection for getline, during a read for getline, or during a close() operation, then ERRNO contains a string describing the error.

In addition, gawk clears ERRNO before opening each command-line input file. This enables checking if the file is readable inside a BEGINFILE pattern (see Section 7.1.5 [The BEGINFILE and ENDFILE Special Patterns], page 123).

Otherwise, `ERRNO` works similarly to the C variable `errno`. Except for the case just mentioned, `gawk` *never* clears it (sets it to zero or `""`). Thus, you should only expect its value to be meaningful when an I/O operation returns a failure value, such as `getline` returning −1. You are, of course, free to clear it yourself before doing an I/O operation.

This variable is a `gawk` extension. In other `awk` implementations, or if `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not special.

`FILENAME` The name of the file that `awk` is currently reading. When no data files are listed on the command line, `awk` reads from the standard input and `FILENAME` is set to `"-"`. `FILENAME` is changed each time a new file is read (see Chapter 4 [Reading Input Files], page 55). Inside a `BEGIN` rule, the value of `FILENAME` is `""`, since there are no input files being processed yet.[3] Note, though, that using `getline` (see Section 4.9 [Explicit Input with `getline`], page 73) inside a `BEGIN` rule can give `FILENAME` a value.

`FNR` The current record number in the current file. `FNR` is incremented each time a new record is read (see Section 4.1 [How Input Is Split into Records], page 55). It is reinitialized to zero each time a new input file is started.

`NF` The number of fields in the current input record. `NF` is set each time a new record is read, when a new field is created or when `$0` changes (see Section 4.2 [Examining Fields], page 58).

Unlike most of the variables described in this section, assigning a value to `NF` has the potential to affect `awk`'s internal workings. In particular, assignments to `NF` can be used to create or remove fields from the current record. See Section 4.4 [Changing the Contents of a Field], page 60.

`FUNCTAB #` An array whose indices and corresponding values are the names of all the user-defined or extension functions in the program.

> **NOTE:** Attempting to use the `delete` statement with the `FUNCTAB` array will cause a fatal error. Any attempt to assign to an element of the `FUNCTAB` array will also cause a fatal error.

`NR` The number of input records `awk` has processed since the beginning of the program's execution (see Section 4.1 [How Input Is Split into Records], page 55). `NR` is incremented each time a new record is read.

`PROCINFO #`

The elements of this array provide access to information about the running `awk` program. The following elements (listed alphabetically) are guaranteed to be available:

`PROCINFO["egid"]`
The value of the `getegid()` system call.

`PROCINFO["euid"]`
The value of the `geteuid()` system call.

[3] Some early implementations of Unix `awk` initialized `FILENAME` to `"-"`, even if there were data files to be processed. This behavior was incorrect and should not be relied upon in your programs.

`PROCINFO["FS"]`
: This is `"FS"` if field splitting with `FS` is in effect, `"FIELDWIDTHS"` if field splitting with `FIELDWIDTHS` is in effect, or `"FPAT"` if field matching with `FPAT` is in effect.

`PROCINFO["identifiers"]`
: A subarray, indexed by the names of all identifiers used in the text of the AWK program. For each identifier, the value of the element is one of the following:

  `"array"` The identifier is an array.

  `"extension"`
  The identifier is an extension function loaded via `@load`.

  `"scalar"` The identifier is a scalar.

  `"untyped"`
  The identifier is untyped (could be used as a scalar or array, `gawk` doesn't know yet).

  `"user"` The identifier is a user-defined function.

  The values indicate what `gawk` knows about the identifiers after it has finished parsing the program; they are *not* updated while the program runs.

`PROCINFO["gid"]`
: The value of the `getgid()` system call.

`PROCINFO["pgrpid"]`
: The process group ID of the current process.

`PROCINFO["pid"]`
: The process ID of the current process.

`PROCINFO["ppid"]`
: The parent process ID of the current process.

`PROCINFO["sorted_in"]`
: If this element exists in `PROCINFO`, its value controls the order in which array indices will be processed by '`for (index in array) ...`' loops. Since this is an advanced feature, we defer the full description until later; see Section 8.1.5 [Scanning All Elements of an Array], page 148.

`PROCINFO["strftime"]`
: The default time format string for `strftime()`. Assigning a new value to this element changes the default. See Section 9.1.5 [Time Functions], page 176.

`PROCINFO["uid"]`
: The value of the `getuid()` system call.

`PROCINFO["version"]`
The version of `gawk`.

The following additional elements in the array are available to provide information about the MPFR and GMP libraries if your version of `gawk` supports arbitrary precision numbers (see Chapter 15 [Arithmetic and Arbitrary Precision Arithmetic with `gawk`], page 317):

`PROCINFO["mpfr_version"]`
The version of the GNU MPFR library.

`PROCINFO["gmp_version"]`
The version of the GNU MP library.

`PROCINFO["prec_max"]`
The maximum precision supported by MPFR.

`PROCINFO["prec_min"]`
The minimum precision required by MPFR.

The following additional elements in the array are available to provide information about the version of the extension API, if your version of `gawk` supports dynamic loading of extension functions (see Chapter 16 [Writing Extensions for `gawk`], page 333):

`PROCINFO["api_major"]`
The major version of the extension API.

`PROCINFO["api_minor"]`
The minor version of the extension API.

On some systems, there may be elements in the array, `"group1"` through `"groupN"` for some *N*. *N* is the number of supplementary groups that the process has. Use the `in` operator to test for these elements (see Section 8.1.2 [Referring to an Array Element], page 146).

The `PROCINFO` array has the following additional uses:

- It may be used to cause coprocesses to communicate over pseudo-ttys instead of through two-way pipes; this is discussed further in Section 12.3 [Two-Way Communications with Another Process], page 283.
- It may be used to provide a timeout when reading from any open input file, pipe, or coprocess. See Section 4.10 [Reading Input With A Timeout], page 79, for more information.

This array is a `gawk` extension. In other `awk` implementations, or if `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not special.

`RLENGTH` The length of the substring matched by the `match()` function (see Section 9.1.3 [String-Manipulation Functions], page 161). `RLENGTH` is set by invoking the `match()` function. Its value is the length of the matched string, or −1 if no match is found.

`RSTART` The start-index in characters of the substring that is matched by the `match()` function (see Section 9.1.3 [String-Manipulation Functions], page 161). `RSTART` is set by invoking the `match()` function. Its value is the position of the string where the matched substring starts, or zero if no match was found.

`RT #` This is set each time a record is read. It contains the input text that matched the text denoted by `RS`, the record separator.

This variable is a `gawk` extension. In other `awk` implementations, or if `gawk` is in compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not special.

`SYMTAB #` An array whose indices are the names of all currently defined global variables and arrays in the program. The array may be used for indirect access to read or write the value of a variable:

```
foo = 5
SYMTAB["foo"] = 4
print foo    # prints 4
```

The `isarray()` function (see Section 9.1.7 [Getting Type Information], page 183) may be used to test if an element in `SYMTAB` is an array. Also, you may not use the `delete` statement with the `SYMTAB` array.

You may use an index for `SYMTAB` that is not a predefined identifer:

```
SYMTAB["xxx"] = 5
print SYMTAB["xxx"]
```

This works as expected: in this case `SYMTAB` acts just like a regular array. The only difference is that you can't then delete `SYMTAB["xxx"]`.

The `SYMTAB` array is more interesting than it looks. Andrew Schorr points out that it effectively gives `awk` data pointers. Consider his example:

```
# Indirect multiply of any variable by amount, return result

function multiply(variable, amount)
{
    return SYMTAB[variable] *= amount
}
```

> **NOTE:** In order to avoid severe time-travel paradoxes[4], neither `FUNCTAB` nor `SYMTAB` are available as elements within the `SYMTAB` array.

[4] Not to mention difficult implementation issues.

Changing `NR` and `FNR`

`awk` increments `NR` and `FNR` each time it reads a record, instead of setting them to the absolute value of the number of records read. This means that a program can change these variables and their new values are incremented for each record. The following example shows this:

```
$ echo '1
> 2
> 3
> 4' | awk 'NR == 2 { NR = 17 }
> { print NR }'
⊣ 1
⊣ 17
⊣ 18
⊣ 19
```

Before `FNR` was added to the `awk` language (see Section A.1 [Major Changes Between V7 and SVR3.1], page 389), many `awk` programs used this feature to track the number of records in a file by resetting `NR` to zero when `FILENAME` changed.

7.5.3 Using `ARGC` and `ARGV`

Section 7.5.2 [Built-in Variables That Convey Information], page 137, presented the following program describing the information contained in `ARGC` and `ARGV`:

```
$ awk 'BEGIN {
>        for (i = 0; i < ARGC; i++)
>            print ARGV[i]
>      }' inventory-shipped BBS-list
⊣ awk
⊣ inventory-shipped
⊣ BBS-list
```

In this example, `ARGV[0]` contains '`awk`', `ARGV[1]` contains '`inventory-shipped`', and `ARGV[2]` contains '`BBS-list`'. Notice that the `awk` program is not entered in `ARGV`. The other command-line options, with their arguments, are also not entered. This includes variable assignments done with the `-v` option (see Section 2.2 [Command-Line Options], page 29). Normal variable assignments on the command line *are* treated as arguments and do show up in the `ARGV` array. Given the following program in a file named `showargs.awk`:

```
BEGIN {
    printf "A=%d, B=%d\n", A, B
    for (i = 0; i < ARGC; i++)
        printf "\tARGV[%d] = %s\n", i, ARGV[i]
}
END   { printf "A=%d, B=%d\n", A, B }
```

Running it produces the following:

```
$ awk -v A=1 -f showargs.awk B=2 /dev/null
⊣ A=1, B=0
⊣        ARGV[0] = awk
⊣        ARGV[1] = B=2
```

```
⊣         ARGV[2] = /dev/null
⊣  A=1, B=2
```

A program can alter ARGC and the elements of ARGV. Each time awk reaches the end of an input file, it uses the next element of ARGV as the name of the next input file. By storing a different string there, a program can change which files are read. Use "-" to represent the standard input. Storing additional elements and incrementing ARGC causes additional files to be read.

If the value of ARGC is decreased, that eliminates input files from the end of the list. By recording the old value of ARGC elsewhere, a program can treat the eliminated arguments as something other than file names.

To eliminate a file from the middle of the list, store the null string ("") into ARGV in place of the file's name. As a special feature, awk ignores file names that have been replaced with the null string. Another option is to use the delete statement to remove elements from ARGV (see Section 8.2 [The delete Statement], page 151).

All of these actions are typically done in the BEGIN rule, before actual processing of the input begins. See Section 11.2.4 [Splitting a Large File into Pieces], page 242, and see Section 11.2.5 [Duplicating Output into Multiple Files], page 244, for examples of each way of removing elements from ARGV. The following fragment processes ARGV in order to examine, and then remove, command-line options:

```
BEGIN {
    for (i = 1; i < ARGC; i++) {
        if (ARGV[i] == "-v")
            verbose = 1
        else if (ARGV[i] == "-q")
            debug = 1
        else if (ARGV[i] ~ /^-./) {
            e = sprintf("%s: unrecognized option -- %c",
                    ARGV[0], substr(ARGV[i], 2, 1))
            print e > "/dev/stderr"
        } else
            break
        delete ARGV[i]
    }
}
```

To actually get the options into the awk program, end the awk options with -- and then supply the awk program's options, in the following manner:

```
awk -f myprog -- -v -q file1 file2 ...
```

This is not necessary in gawk. Unless --posix has been specified, gawk silently puts any unrecognized options into ARGV for the awk program to deal with. As soon as it sees an unknown option, gawk stops looking for other options that it might otherwise recognize. The previous example with gawk would be:

```
gawk -f myprog -q -v file1 file2 ...
```

Because -q is not a valid gawk option, it and the following -v are passed on to the awk program. (See Section 10.4 [Processing Command-Line Options], page 216, for an awk library function that parses command-line options.)

8 Arrays in awk

An *array* is a table of values called *elements*. The elements of an array are distinguished by their *indices*. Indices may be either numbers or strings.

This chapter describes how arrays work in awk, how to use array elements, how to scan through every element in an array, and how to remove array elements. It also describes how awk simulates multidimensional arrays, as well as some of the less obvious points about array usage. The chapter moves on to discuss gawk's facility for sorting arrays, and ends with a brief description of gawk's ability to support true multidimensional arrays.

awk maintains a single set of names that may be used for naming variables, arrays, and functions (see Section 9.2 [User-Defined Functions], page 184). Thus, you cannot have a variable and an array with the same name in the same awk program.

8.1 The Basics of Arrays

This section presents the basics: working with elements in arrays one at a time, and traversing all of the elements in an array.

8.1.1 Introduction to Arrays

> *Doing linear scans over an associative array is like trying to club someone to death with a loaded Uzi.*
> Larry Wall

The awk language provides one-dimensional arrays for storing groups of related strings or numbers. Every awk array must have a name. Array names have the same syntax as variable names; any valid variable name would also be a valid array name. But one name cannot be used in both ways (as an array and as a variable) in the same awk program.

Arrays in awk superficially resemble arrays in other programming languages, but there are fundamental differences. In awk, it isn't necessary to specify the size of an array before starting to use it. Additionally, any number or string in awk, not just consecutive integers, may be used as an array index.

In most other languages, arrays must be *declared* before use, including a specification of how many elements or components they contain. In such languages, the declaration causes a contiguous block of memory to be allocated for that many elements. Usually, an index in the array must be a positive integer. For example, the index zero specifies the first element in the array, which is actually stored at the beginning of the block of memory. Index one specifies the second element, which is stored in memory right after the first element, and so on. It is impossible to add more elements to the array, because it has room only for as many elements as given in the declaration. (Some languages allow arbitrary starting and ending indices—e.g., '15 .. 27'—but the size of the array is still fixed when the array is declared.)

A contiguous array of four elements might look like the following example, conceptually, if the element values are 8, "foo", "", and 30:

8	"foo"	""	30	Value
0	1	2	3	Index

Only the values are stored; the indices are implicit from the order of the values. Here, 8 is the value at index zero, because 8 appears in the position with zero elements before it.

Arrays in `awk` are different—they are *associative*. This means that each array is a collection of pairs: an index and its corresponding array element value:

Index	`3`	Value	`30`
Index	`1`	Value	`"foo"`
Index	`0`	Value	`8`
Index	`2`	Value	`""`

The pairs are shown in jumbled order because their order is irrelevant.

One advantage of associative arrays is that new pairs can be added at any time. For example, suppose a tenth element is added to the array whose value is `"number ten"`. The result is:

Index	`10`	Value	`"number ten"`
Index	`3`	Value	`30`
Index	`1`	Value	`"foo"`
Index	`0`	Value	`8`
Index	`2`	Value	`""`

Now the array is *sparse*, which just means some indices are missing. It has elements 0–3 and 10, but doesn't have elements 4, 5, 6, 7, 8, or 9.

Another consequence of associative arrays is that the indices don't have to be positive integers. Any number, or even a string, can be an index. For example, the following is an array that translates words from English to French:

Index	`"dog"`	Value	`"chien"`
Index	`"cat"`	Value	`"chat"`
Index	`"one"`	Value	`"un"`
Index	`1`	Value	`"un"`

Here we decided to translate the number one in both spelled-out and numeric form—thus illustrating that a single array can have both numbers and strings as indices. In fact, array subscripts are always strings; this is discussed in more detail in Section 8.3 [Using Numbers to Subscript Arrays], page 153. Here, the number `1` isn't double-quoted, since `awk` automatically converts it to a string.

The value of `IGNORECASE` has no effect upon array subscripting. The identical string value used to store an array element must be used to retrieve it. When `awk` creates an array (e.g., with the `split()` built-in function), that array's indices are consecutive integers starting at one. (See Section 9.1.3 [String-Manipulation Functions], page 161.)

`awk`'s arrays are efficient—the time to access an element is independent of the number of elements in the array.

8.1.2 Referring to an Array Element

The principal way to use an array is to refer to one of its elements. An array reference is an expression as follows:

```
array[index-expression]
```

Here, *array* is the name of an array. The expression *index-expression* is the index of the desired element of the array.

The value of the array reference is the current value of that array element. For example, `foo[4.3]` is an expression for the element of array `foo` at index '4.3'.

A reference to an array element that has no recorded value yields a value of `""`, the null string. This includes elements that have not been assigned any value as well as elements that have been deleted (see Section 8.2 [The `delete` Statement], page 151).

> **NOTE:** A reference to an element that does not exist *automatically* creates that array element, with the null string as its value. (In some cases, this is unfortunate, because it might waste memory inside `awk`.)
>
> Novice `awk` programmers often make the mistake of checking if an element exists by checking if the value is empty:
>
> ```
> # Check if "foo" exists in a:         Incorrect!
> if (a["foo"] != "") ...
> ```
>
> This is incorrect, since this will *create* `a["foo"]` if it didn't exist before!

To determine whether an element exists in an array at a certain index, use the following expression:

```
ind in array
```

This expression tests whether the particular index *ind* exists, without the side effect of creating that element if it is not present. The expression has the value one (true) if `array[ind]` exists and zero (false) if it does not exist. For example, this statement tests whether the array `frequencies` contains the index '2':

```
if (2 in frequencies)
    print "Subscript 2 is present."
```

Note that this is *not* a test of whether the array `frequencies` contains an element whose *value* is two. There is no way to do that except to scan all the elements. Also, this *does not* create `frequencies[2]`, while the following (incorrect) alternative does:

```
if (frequencies[2] != "")
    print "Subscript 2 is present."
```

8.1.3 Assigning Array Elements

Array elements can be assigned values just like `awk` variables:

```
array[index-expression] = value
```

array is the name of an array. The expression *index-expression* is the index of the element of the array that is assigned a value. The expression *value* is the value to assign to that element of the array.

8.1.4 Basic Array Example

The following program takes a list of lines, each beginning with a line number, and prints them out in order of line number. The line numbers are not in order when they are first read—instead they are scrambled. This program sorts the lines by making an array using the line numbers as subscripts. The program then prints out the lines in sorted order of their numbers. It is a very simple program and gets confused upon encountering repeated numbers, gaps, or lines that don't begin with a number:

```
{
  if ($1 > max)
    max = $1
  arr[$1] = $0
}

END {
  for (x = 1; x <= max; x++)
    print arr[x]
}
```

The first rule keeps track of the largest line number seen so far; it also stores each line into the array `arr`, at an index that is the line's number. The second rule runs after all the input has been read, to print out all the lines. When this program is run with the following input:

```
5  I am the Five man
2  Who are you?  The new number two!
4  . . . And four on the floor
1  Who is number one?
3  I three you.
```

Its output is:

```
1  Who is number one?
2  Who are you?  The new number two!
3  I three you.
4  . . . And four on the floor
5  I am the Five man
```

If a line number is repeated, the last line with a given number overrides the others. Gaps in the line numbers can be handled with an easy improvement to the program's `END` rule, as follows:

```
END {
  for (x = 1; x <= max; x++)
    if (x in arr)
      print arr[x]
}
```

8.1.5 Scanning All Elements of an Array

In programs that use arrays, it is often necessary to use a loop that executes once for each element of an array. In other languages, where arrays are contiguous and indices are limited to positive integers, this is easy: all the valid indices can be found by counting from the lowest index up to the highest. This technique won't do the job in `awk`, because any number or string can be an array index. So `awk` has a special kind of `for` statement for scanning an array:

```
for (var in array)
  body
```

This loop executes *body* once for each index in *array* that the program has previously used, with the variable *var* set to that index.

The following program uses this form of the for statement. The first rule scans the input records and notes which words appear (at least once) in the input, by storing a one into the array used with the word as index. The second rule scans the elements of used to find all the distinct words that appear in the input. It prints each word that is more than 10 characters long and also prints the number of such words. See Section 9.1.3 [String-Manipulation Functions], page 161, for more information on the built-in function length().

```
# Record a 1 for each word that is used at least once
{
    for (i = 1; i <= NF; i++)
        used[$i] = 1
}

# Find number of distinct words more than 10 characters long
END {
    for (x in used) {
        if (length(x) > 10) {
            ++num_long_words
            print x
        }
    }
    print num_long_words, "words longer than 10 characters"
}
```

See Section 11.3.5 [Generating Word-Usage Counts], page 259, for a more detailed example of this type.

The order in which elements of the array are accessed by this statement is determined by the internal arrangement of the array elements within awk and normally cannot be controlled or changed. This can lead to problems if new elements are added to *array* by statements in the loop body; it is not predictable whether the for loop will reach them. Similarly, changing *var* inside the loop may produce strange results. It is best to avoid such things.

8.1.6 Using Predefined Array Scanning Orders

By default, when a for loop traverses an array, the order is undefined, meaning that the awk implementation determines the order in which the array is traversed. This order is usually based on the internal implementation of arrays and will vary from one version of awk to the next.

Often, though, you may wish to do something simple, such as "traverse the array by comparing the indices in ascending order," or "traverse the array by comparing the values in descending order." gawk provides two mechanisms which give you this control.

- Set PROCINFO["sorted_in"] to one of a set of predefined values. We describe this now.
- Set PROCINFO["sorted_in"] to the name of a user-defined function to use for comparison of array elements. This advanced feature is described later, in Section 12.2 [Controlling Array Traversal and Array Sorting], page 278.

The following special values for `PROCINFO["sorted_in"]` are available:

`"@unsorted"`
: Array elements are processed in arbitrary order, which is the default `awk` behavior.

`"@ind_str_asc"`
: Order by indices compared as strings; this is the most basic sort. (Internally, array indices are always strings, so with '`a[2*5] = 1`' the index is `"10"` rather than numeric 10.)

`"@ind_num_asc"`
: Order by indices but force them to be treated as numbers in the process. Any index with a non-numeric value will end up positioned as if it were zero.

`"@val_type_asc"`
: Order by element values rather than indices. Ordering is by the type assigned to the element (see Section 6.3.2 [Variable Typing and Comparison Expressions], page 110). All numeric values come before all string values, which in turn come before all subarrays. (Subarrays have not been described yet; see Section 8.6 [Arrays of Arrays], page 156).

`"@val_str_asc"`
: Order by element values rather than by indices. Scalar values are compared as strings. Subarrays, if present, come out last.

`"@val_num_asc"`
: Order by element values rather than by indices. Scalar values are compared as numbers. Subarrays, if present, come out last. When numeric values are equal, the string values are used to provide an ordering: this guarantees consistent results across different versions of the C `qsort()` function,[1] which `gawk` uses internally to perform the sorting.

`"@ind_str_desc"`
: Reverse order from the most basic sort.

`"@ind_num_desc"`
: Numeric indices ordered from high to low.

`"@val_type_desc"`
: Element values, based on type, in descending order.

`"@val_str_desc"`
: Element values, treated as strings, ordered from high to low. Subarrays, if present, come out first.

`"@val_num_desc"`
: Element values, treated as numbers, ordered from high to low. Subarrays, if present, come out first.

---

[1] When two elements compare as equal, the C `qsort()` function does not guarantee that they will maintain their original relative order after sorting. Using the string value to provide a unique ordering when the numeric values are equal ensures that `gawk` behaves consistently across different environments.

The array traversal order is determined before the for loop starts to run. Changing PROCINFO["sorted_in"] in the loop body does not affect the loop. For example:

```
$ gawk 'BEGIN {
>    a[4] = 4
>    a[3] = 3
>    for (i in a)
>        print i, a[i]
> }'
⊣ 4 4
⊣ 3 3
$ gawk 'BEGIN {
>    PROCINFO["sorted_in"] = "@ind_str_asc"
>    a[4] = 4
>    a[3] = 3
>    for (i in a)
>        print i, a[i]
> }'
⊣ 3 3
⊣ 4 4
```

When sorting an array by element values, if a value happens to be a subarray then it is considered to be greater than any string or numeric value, regardless of what the subarray itself contains, and all subarrays are treated as being equal to each other. Their order relative to each other is determined by their index strings.

Here are some additional things to bear in mind about sorted array traversal.

- The value of PROCINFO["sorted_in"] is global. That is, it affects all array traversal for loops. If you need to change it within your own code, you should see if it's defined and save and restore the value:

```
...
if ("sorted_in" in PROCINFO) {
    save_sorted = PROCINFO["sorted_in"]
    PROCINFO["sorted_in"] = "@val_str_desc" # or whatever
}
...
if (save_sorted)
    PROCINFO["sorted_in"] = save_sorted
```

- As mentioned, the default array traversal order is represented by "@unsorted". You can also get the default behavior by assigning the null string to PROCINFO["sorted_in"] or by just deleting the "sorted_in" element from the PROCINFO array with the delete statement. (The delete statement hasn't been described yet; see Section 8.2 [The delete Statement], page 151.)

In addition, gawk provides built-in functions for sorting arrays; see Section 12.2.2 [Sorting Array Values and Indices with gawk], page 282.

8.2 The delete Statement

To remove an individual element of an array, use the delete statement:

```
delete array[index-expression]
```

Once an array element has been deleted, any value the element once had is no longer available. It is as if the element had never been referred to or been given a value. The following is an example of deleting elements in an array:

```
for (i in frequencies)
  delete frequencies[i]
```

This example removes all the elements from the array `frequencies`. Once an element is deleted, a subsequent `for` statement to scan the array does not report that element and the `in` operator to check for the presence of that element returns zero (i.e., false):

```
delete foo[4]
if (4 in foo)
    print "This will never be printed"
```

It is important to note that deleting an element is *not* the same as assigning it a null value (the empty string, `""`). For example:

```
foo[4] = ""
if (4 in foo)
  print "This is printed, even though foo[4] is empty"
```

It is not an error to delete an element that does not exist. However, if `--lint` is provided on the command line (see Section 2.2 [Command-Line Options], page 29), `gawk` issues a warning message when an element that is not in the array is deleted.

All the elements of an array may be deleted with a single statement by leaving off the subscript in the `delete` statement, as follows:

```
delete array
```

Using this version of the `delete` statement is about three times more efficient than the equivalent loop that deletes each element one at a time.

> **NOTE:** For many years, using `delete` without a subscript was a `gawk` extension. As of September, 2012, it was accepted for inclusion into the POSIX standard. See the Austin Group website (`http://austingroupbugs.net/view.php?id=544`). This form of the `delete` statement is also supported by Brian Kernighan's `awk` and `mawk`, as well as by a number of other implementations (see Section B.5 [Other Freely Available `awk` Implementations], page 412).

The following statement provides a portable but nonobvious way to clear out an array:[2]

```
split("", array)
```

The `split()` function (see Section 9.1.3 [String-Manipulation Functions], page 161) clears out the target array first. This call asks it to split apart the null string. Because there is no data to split out, the function simply clears the array and then returns.

> **CAUTION:** Deleting an array does not change its type; you cannot delete an array and then use the array's name as a scalar (i.e., a regular variable). For example, the following does not work:
>
> ```
> a[1] = 3
> delete a
> a = 3
> ```

[2] Thanks to Michael Brennan for pointing this out.

8.3 Using Numbers to Subscript Arrays

An important aspect to remember about arrays is that *array subscripts are always strings*. When a numeric value is used as a subscript, it is converted to a string value before being used for subscripting (see Section 6.1.4 [Conversion of Strings and Numbers], page 101). This means that the value of the built-in variable `CONVFMT` can affect how your program accesses elements of an array. For example:

```
xyz = 12.153
data[xyz] = 1
CONVFMT = "%2.2f"
if (xyz in data)
    printf "%s is in data\n", xyz
else
    printf "%s is not in data\n", xyz
```

This prints '`12.15 is not in data`'. The first statement gives `xyz` a numeric value. Assigning to `data[xyz]` subscripts `data` with the string value `"12.153"` (using the default conversion value of `CONVFMT`, `"%.6g"`). Thus, the array element `data["12.153"]` is assigned the value one. The program then changes the value of `CONVFMT`. The test '`(xyz in data)`' generates a new string value from `xyz`—this time `"12.15"`—because the value of `CONVFMT` only allows two significant digits. This test fails, since `"12.15"` is different from `"12.153"`.

According to the rules for conversions (see Section 6.1.4 [Conversion of Strings and Numbers], page 101), integer values are always converted to strings as integers, no matter what the value of `CONVFMT` may happen to be. So the usual case of the following works:

```
for (i = 1; i <= maxsub; i++)
    do something with array[i]
```

The "integer values always convert to strings as integers" rule has an additional consequence for array indexing. Octal and hexadecimal constants (see Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97) are converted internally into numbers, and their original form is forgotten. This means, for example, that `array[17]`, `array[021]`, and `array[0x11]` all refer to the same element!

As with many things in `awk`, the majority of the time things work as one would expect them to. But it is useful to have a precise knowledge of the actual rules since they can sometimes have a subtle effect on your programs.

8.4 Using Uninitialized Variables as Subscripts

Suppose it's necessary to write a program to print the input data in reverse order. A reasonable attempt to do so (with some test data) might look like this:

```
$ echo 'line 1
> line 2
> line 3' | awk '{ l[lines] = $0; ++lines }
> END {
>     for (i = lines-1; i >= 0; --i)
>        print l[i]
> }'
```

```
⊣ line 3
⊣ line 2
```

Unfortunately, the very first line of input data did not come out in the output!

Upon first glance, we would think that this program should have worked. The variable `lines` is uninitialized, and uninitialized variables have the numeric value zero. So, `awk` should have printed the value of `l[0]`.

The issue here is that subscripts for `awk` arrays are *always* strings. Uninitialized variables, when used as strings, have the value `""`, not zero. Thus, '`line 1`' ends up stored in `l[""]`. The following version of the program works correctly:

```
{ l[lines++] = $0 }
END {
    for (i = lines - 1; i >= 0; --i)
       print l[i]
}
```

Here, the '`++`' forces `lines` to be numeric, thus making the "old value" numeric zero. This is then converted to `"0"` as the array subscript.

Even though it is somewhat unusual, the null string (`""`) is a valid array subscript. `gawk` warns about the use of the null string as a subscript if `--lint` is provided on the command line (see Section 2.2 [Command-Line Options], page 29).

8.5 Multidimensional Arrays

A multidimensional array is an array in which an element is identified by a sequence of indices instead of a single index. For example, a two-dimensional array requires two indices. The usual way (in most languages, including `awk`) to refer to an element of a two-dimensional array named `grid` is with `grid[x,y]`.

Multidimensional arrays are supported in `awk` through concatenation of indices into one string. `awk` converts the indices into strings (see Section 6.1.4 [Conversion of Strings and Numbers], page 101) and concatenates them together, with a separator between them. This creates a single string that describes the values of the separate indices. The combined string is used as a single index into an ordinary, one-dimensional array. The separator used is the value of the built-in variable `SUBSEP`.

For example, suppose we evaluate the expression '`foo[5,12] = "value"`' when the value of `SUBSEP` is `"@"`. The numbers 5 and 12 are converted to strings and concatenated with an '`@`' between them, yielding `"5@12"`; thus, the array element `foo["5@12"]` is set to `"value"`.

Once the element's value is stored, `awk` has no record of whether it was stored with a single index or a sequence of indices. The two expressions '`foo[5,12]`' and '`foo[5 SUBSEP 12]`' are always equivalent.

The default value of `SUBSEP` is the string `"\034"`, which contains a nonprinting character that is unlikely to appear in an `awk` program or in most input data. The usefulness of choosing an unlikely character comes from the fact that index values that contain a string matching `SUBSEP` can lead to combined strings that are ambiguous. Suppose that `SUBSEP` is `"@"`; then '`foo["a@b", "c"]`' and '`foo["a", "b@c"]`' are indistinguishable because both are actually stored as '`foo["a@b@c"]`'.

To test whether a particular index sequence exists in a multidimensional array, use the same operator (`in`) that is used for single dimensional arrays. Write the whole sequence of indices in parentheses, separated by commas, as the left operand:

```
(subscript1, subscript2, ...) in array
```

The following example treats its input as a two-dimensional array of fields; it rotates this array 90 degrees clockwise and prints the result. It assumes that all lines have the same number of elements:

```
{
     if (max_nf < NF)
          max_nf = NF
     max_nr = NR
     for (x = 1; x <= NF; x++)
          vector[x, NR] = $x
}

END {
     for (x = 1; x <= max_nf; x++) {
          for (y = max_nr; y >= 1; --y)
               printf("%s ", vector[x, y])
          printf("\n")
     }
}
```

When given the input:

```
1 2 3 4 5 6
2 3 4 5 6 1
3 4 5 6 1 2
4 5 6 1 2 3
```

the program produces the following output:

```
4 3 2 1
5 4 3 2
6 5 4 3
1 6 5 4
2 1 6 5
3 2 1 6
```

8.5.1 Scanning Multidimensional Arrays

There is no special `for` statement for scanning a "multidimensional" array. There cannot be one, because, in truth, `awk` does not have multidimensional arrays or elements—there is only a multidimensional *way of accessing* an array.

However, if your program has an array that is always accessed as multidimensional, you can get the effect of scanning it by combining the scanning `for` statement (see Section 8.1.5 [Scanning All Elements of an Array], page 148) with the built-in `split()` function (see Section 9.1.3 [String-Manipulation Functions], page 161). It works in the following manner:

```
for (combined in array) {
    split(combined, separate, SUBSEP)
```

```
        ...
    }
```

This sets the variable `combined` to each concatenated combined index in the array, and splits it into the individual indices by breaking it apart where the value of `SUBSEP` appears. The individual indices then become the elements of the array `separate`.

Thus, if a value is previously stored in `array[1, "foo"]`, then an element with index `"1\034foo"` exists in `array`. (Recall that the default value of `SUBSEP` is the character with code 034.) Sooner or later, the `for` statement finds that index and does an iteration with the variable `combined` set to `"1\034foo"`. Then the `split()` function is called as follows:

```
split("1\034foo", separate, "\034")
```

The result is to set `separate[1]` to `"1"` and `separate[2]` to `"foo"`. Presto! The original sequence of separate indices is recovered.

8.6 Arrays of Arrays

`gawk` goes beyond standard `awk`'s multidimensional array access and provides true arrays of arrays. Elements of a subarray are referred to by their own indices enclosed in square brackets, just like the elements of the main array. For example, the following creates a two-element subarray at index '1' of the main array `a`:

```
a[1][1] = 1
a[1][2] = 2
```

This simulates a true two-dimensional array. Each subarray element can contain another subarray as a value, which in turn can hold other arrays as well. In this way, you can create arrays of three or more dimensions. The indices can be any `awk` expression, including scalars separated by commas (that is, a regular `awk` simulated multidimensional subscript). So the following is valid in `gawk`:

```
a[1][3][1, "name"] = "barney"
```

Each subarray and the main array can be of different length. In fact, the elements of an array or its subarray do not all have to have the same type. This means that the main array and any of its subarrays can be non-rectangular, or jagged in structure. One can assign a scalar value to the index '4' of the main array `a`:

```
a[4] = "An element in a jagged array"
```

The terms *dimension*, *row* and *column* are meaningless when applied to such an array, but we will use "dimension" henceforth to imply the maximum number of indices needed to refer to an existing element. The type of any element that has already been assigned cannot be changed by assigning a value of a different type. You have to first delete the current element, which effectively makes `gawk` forget about the element at that index:

```
delete a[4]
a[4][5][6][7] = "An element in a four-dimensional array"
```

This removes the scalar value from index '4' and then inserts a subarray of subarray of subarray containing a scalar. You can also delete an entire subarray or subarray of subarrays:

```
delete a[4][5]
a[4][5] = "An element in subarray a[4]"
```

But recall that you can not delete the main array `a` and then use it as a scalar.

The built-in functions which take array arguments can also be used with subarrays. For example, the following code fragment uses `length()` (see Section 9.1.3 [String-Manipulation Functions], page 161) to determine the number of elements in the main array `a` and its subarrays:

```
print length(a), length(a[1]), length(a[1][3])
```

This results in the following output for our main array `a`:

```
2, 3, 1
```

The '*subscript* `in` *array*' expression (see Section 8.1.2 [Referring to an Array Element], page 146) works similarly for both regular `awk`-style arrays and arrays of arrays. For example, the tests '`1 in a`', '`3 in a[1]`', and '`(1, "name") in a[1][3]`' all evaluate to one (true) for our array `a`.

The '`for (item in array)`' statement (see Section 8.1.5 [Scanning All Elements of an Array], page 148) can be nested to scan all the elements of an array of arrays if it is rectangular in structure. In order to print the contents (scalar values) of a two-dimensional array of arrays (i.e., in which each first-level element is itself an array, not necessarily of the same length) you could use the following code:

```
for (i in array)
    for (j in array[i])
        print array[i][j]
```

The `isarray()` function (see Section 9.1.7 [Getting Type Information], page 183) lets you test if an array element is itself an array:

```
for (i in array) {
    if (isarray(array[i]) {
        for (j in array[i]) {
            print array[i][j]
        }
    }
}
```

If the structure of a jagged array of arrays is known in advance, you can often devise workarounds using control statements. For example, the following code prints the elements of our main array `a`:

```
for (i in a) {
    for (j in a[i]) {
        if (j == 3) {
            for (k in a[i][j])
                print a[i][j][k]
        } else
            print a[i][j]
    }
}
```

See Section 10.7 [Traversing Arrays of Arrays], page 229, for a user-defined function that "walks" an arbitrarily-dimensioned array of arrays.

Recall that a reference to an uninitialized array element yields a value of `""`, the null string. This has one important implication when you intend to use a subarray as an argument to a function, as illustrated by the following example:

```
$ gawk 'BEGIN { split("a b c d", b[1]); print b[1][1] }'
error gawk: cmd. line:1: fatal: split: second argument is not an array
```

The way to work around this is to first force `b[1]` to be an array by creating an arbitrary index:

```
$ gawk 'BEGIN { b[1][1] = ""; split("a b c d", b[1]); print b[1][1] }'
⊣ a
```

9 Functions

This chapter describes awk's built-in functions, which fall into three categories: numeric, string, and I/O. gawk provides additional groups of functions to work with values that represent time, do bit manipulation, sort arrays, and internationalize and localize programs.

Besides the built-in functions, awk has provisions for writing new functions that the rest of a program can use. The second half of this chapter describes these *user-defined* functions.

9.1 Built-in Functions

Built-in functions are always available for your awk program to call. This section defines all the built-in functions in awk; some of these are mentioned in other sections but are summarized here for your convenience.

9.1.1 Calling Built-in Functions

To call one of awk's built-in functions, write the name of the function followed by arguments in parentheses. For example, 'atan2(y + z, 1)' is a call to the function atan2() and has two arguments.

Whitespace is ignored between the built-in function name and the open parenthesis, but nonetheless it is good practice to avoid using whitespace there. User-defined functions do not permit whitespace in this way, and it is easier to avoid mistakes by following a simple convention that always works—no whitespace after a function name.

Each built-in function accepts a certain number of arguments. In some cases, arguments can be omitted. The defaults for omitted arguments vary from function to function and are described under the individual functions. In some awk implementations, extra arguments given to built-in functions are ignored. However, in gawk, it is a fatal error to give extra arguments to a built-in function.

When a function is called, expressions that create the function's actual parameters are evaluated completely before the call is performed. For example, in the following code fragment:

```
i = 4
j = sqrt(i++)
```

the variable i is incremented to the value five before sqrt() is called with a value of four for its actual parameter. The order of evaluation of the expressions used for the function's parameters is undefined. Thus, avoid writing programs that assume that parameters are evaluated from left to right or from right to left. For example:

```
i = 5
j = atan2(i++, i *= 2)
```

If the order of evaluation is left to right, then i first becomes 6, and then 12, and atan2() is called with the two arguments 6 and 12. But if the order of evaluation is right to left, i first becomes 10, then 11, and atan2() is called with the two arguments 11 and 10.

9.1.2 Numeric Functions

The following list describes all of the built-in functions that work with numbers. Optional parameters are enclosed in square brackets ([ ]):

`atan2(y, x)`
: Return the arctangent of `y / x` in radians. You can use '`pi = atan2(0, -1)`' to retrieve the value of π.

`cos(x)`
: Return the cosine of *x*, with *x* in radians.

`exp(x)`
: Return the exponential of *x* (`e ^ x`) or report an error if *x* is out of range. The range of values *x* can have depends on your machine's floating-point representation.

`int(x)`
: Return the nearest integer to *x*, located between *x* and zero and truncated toward zero.

For example, `int(3)` is 3, `int(3.9)` is 3, `int(-3.9)` is −3, and `int(-3)` is −3 as well.

`log(x)`
: Return the natural logarithm of *x*, if *x* is positive; otherwise, report an error.

`rand()`
: Return a random number. The values of `rand()` are uniformly distributed between zero and one. The value could be zero but is never one.[1]

Often random integers are needed instead. Following is a user-defined function that can be used to obtain a random non-negative integer less than *n*:

```
function randint(n) {
     return int(n * rand())
}
```

The multiplication produces a random number greater than zero and less than `n`. Using `int()`, this result is made into an integer between zero and `n` − 1, inclusive.

The following example uses a similar function to produce random integers between one and *n*. This program prints a new random number for each input record:

```
# Function to roll a simulated die.
function roll(n) { return 1 + int(rand() * n) }

# Roll 3 six-sided dice and
# print total number of points.
{
      printf("%d points\n",
             roll(6)+roll(6)+roll(6))
}
```

CAUTION: In most `awk` implementations, including `gawk`, `rand()` starts generating numbers from the same starting number, or *seed*, each time you run `awk`.[2] Thus, a program generates the same results each time you run it. The numbers are random within one `awk` run

[1] The C version of `rand()` on many Unix systems is known to produce fairly poor sequences of random numbers. However, nothing requires that an `awk` implementation use the C `rand()` to implement the `awk` version of `rand()`. In fact, `gawk` uses the BSD `random()` function, which is considerably better than `rand()`, to produce random numbers.

[2] `mawk` uses a different seed each time.

but predictable from run to run. This is convenient for debugging, but if you want a program to do different things each time it is used, you must change the seed to a value that is different in each run. To do this, use `srand()`.

`sin(x)` Return the sine of *x*, with *x* in radians.

`sqrt(x)` Return the positive square root of *x*. `gawk` prints a warning message if *x* is negative. Thus, `sqrt(4)` is 2.

`srand([x])`
Set the starting point, or seed, for generating random numbers to the value *x*.

Each seed value leads to a particular sequence of random numbers.[3] Thus, if the seed is set to the same value a second time, the same sequence of random numbers is produced again.

> **CAUTION:** Different `awk` implementations use different random-number generators internally. Don't expect the same `awk` program to produce the same series of random numbers when executed by different versions of `awk`.

If the argument *x* is omitted, as in '`srand()`', then the current date and time of day are used for a seed. This is the way to get random numbers that are truly unpredictable.

The return value of `srand()` is the previous seed. This makes it easy to keep track of the seeds in case you need to consistently reproduce sequences of random numbers.

9.1.3 String-Manipulation Functions

The functions in this section look at or change the text of one or more strings. `gawk` understands locales (see Section 6.6 [Where You Are Makes A Difference], page 118), and does all string processing in terms of *characters*, not *bytes*. This distinction is particularly important to understand for locales where one character may be represented by multiple bytes. Thus, for example, `length()` returns the number of characters in a string, and not the number of bytes used to represent those characters, Similarly, `index()` works with character indices, and not byte indices.

In the following list, optional parameters are enclosed in square brackets ([ ]). Several functions perform string substitution; the full discussion is provided in the description of the `sub()` function, which comes towards the end since the list is presented in alphabetic order. Those functions that are specific to `gawk` are marked with a pound sign ('`#`'):

`asort(source [, dest [, how ] ]) #`
Return the number of elements in the array *source*. `gawk` sorts the contents of *source* and replaces the indices of the sorted values of *source* with sequential integers starting with one. If the optional array *dest* is specified, then *source* is duplicated into *dest*. *dest* is then sorted, leaving the indices of *source*

---

[3] Computer-generated random numbers really are not truly random. They are technically known as "pseudorandom." This means that while the numbers in a sequence appear to be random, you can in fact generate the same sequence of random numbers over and over again.

unchanged. The optional third argument *how* is a string which controls the rule for comparing values, and the sort direction. A single space is required between the comparison mode, '`string`' or '`number`', and the direction specification, '`ascending`' or '`descending`'. You can omit direction and/or mode in which case it will default to '`ascending`' and '`string`', respectively. An empty string `""` is the same as the default `"ascending string"` for the value of *how*. If the '`source`' array contains subarrays as values, they will come out last(first) in the '`dest`' array for '`ascending`'('`descending`') order specification. The value of `IGNORECASE` affects the sorting. The third argument can also be a user-defined function name in which case the value returned by the function is used to order the array elements before constructing the result array. See Section 12.2.2 [Sorting Array Values and Indices with gawk], page 282, for more information.

For example, if the contents of `a` are as follows:

```
a["last"] = "de"
a["first"] = "sac"
a["middle"] = "cul"
```

A call to `asort()`:

```
asort(a)
```

results in the following contents of `a`:

```
a[1] = "cul"
a[2] = "de"
a[3] = "sac"
```

In order to reverse the direction of the sorted results in the above example, `asort()` can be called with three arguments as follows:

```
asort(a, a, "descending")
```

The `asort()` function is described in more detail in Section 12.2.2 [Sorting Array Values and Indices with `gawk`], page 282. `asort()` is a `gawk` extension; it is not available in compatibility mode (see Section 2.2 [Command-Line Options], page 29).

`asorti(`*`source`* [`,` *`dest`* [`,` *`how`*]]`) #`

Return the number of elements in the array *source*. It works similarly to `asort()`, however, the *indices* are sorted, instead of the values. (Here too, `IGNORECASE` affects the sorting.)

The `asorti()` function is described in more detail in Section 12.2.2 [Sorting Array Values and Indices with `gawk`], page 282. `asorti()` is a `gawk` extension; it is not available in compatibility mode (see Section 2.2 [Command-Line Options], page 29).

`gensub(`*`regexp`*`,` *`replacement`*`,` *`how`* [`,` *`target`*]`) #`

Search the target string *target* for matches of the regular expression *regexp*. If *how* is a string beginning with '`g`' or '`G`' (short for "global"), then replace all matches of *regexp* with *replacement*. Otherwise, *how* is treated as a number indicating which match of *regexp* to replace. If no *target* is supplied, use `$0`. It returns the modified string as the result of the function and the original target string is *not* changed.

gensub() is a general substitution function. It's purpose is to provide more features than the standard sub() and gsub() functions.

gensub() provides an additional feature that is not available in sub() or gsub(): the ability to specify components of a regexp in the replacement text. This is done by using parentheses in the regexp to mark the components and then specifying '\N' in the replacement text, where *N* is a digit from 1 to 9. For example:

```
$ gawk '
> BEGIN {
>      a = "abc def"
>      b = gensub(/(.+) (.+)/, "\\2 \\1", "g", a)
>      print b
> }'
⊣ def abc
```

As with sub(), you must type two backslashes in order to get one into the string. In the replacement text, the sequence '\0' represents the entire matched text, as does the character '&'.

The following example shows how you can use the third argument to control which match of the regexp should be changed:

```
$ echo a b c a b c |
> gawk '{ print gensub(/a/, "AA", 2) }'
⊣ a b c AA b c
```

In this case, $0 is the default target string. gensub() returns the new string as its result, which is passed directly to print for printing.

If the *how* argument is a string that does not begin with 'g' or 'G', or if it is a number that is less than or equal to zero, only one substitution is performed. If *how* is zero, gawk issues a warning message.

If *regexp* does not match *target*, gensub()'s return value is the original unchanged value of *target*.

gensub() is a gawk extension; it is not available in compatibility mode (see Section 2.2 [Command-Line Options], page 29).

gsub(*regexp*, *replacement* [, *target*])

Search *target* for *all* of the longest, leftmost, *nonoverlapping* matching substrings it can find and replace them with *replacement*. The 'g' in gsub() stands for "global," which means replace everywhere. For example:

```
{ gsub(/Britain/, "United Kingdom"); print }
```

replaces all occurrences of the string 'Britain' with 'United Kingdom' for all input records.

The gsub() function returns the number of substitutions made. If the variable to search and alter (*target*) is omitted, then the entire input record ($0) is used. As in sub(), the characters '&' and '\' are special, and the third argument must be assignable.

`index(in, find)`

Search the string *in* for the first occurrence of the string *find*, and return the position in characters where that occurrence begins in the string *in*. Consider the following example:

```
$ awk 'BEGIN { print index("peanut", "an") }'
⊣ 3
```

If *find* is not found, `index()` returns zero. (Remember that string indices in `awk` start at one.)

It is a fatal error to use a regexp constant for *find*.

`length([string])`

Return the number of characters in *string*. If *string* is a number, the length of the digit string representing that number is returned. For example, `length("abcde")` is five. By contrast, `length(15 * 35)` works out to three. In this example, 15 * 35 = 525, and 525 is then converted to the string `"525"`, which has three characters.

If no argument is supplied, `length()` returns the length of `$0`.

> **NOTE:** In older versions of `awk`, the `length()` function could be called without any parentheses. Doing so is considered poor practice, although the 2008 POSIX standard explicitly allows it, to support historical practice. For programs to be maximally portable, always supply the parentheses.

If `length()` is called with a variable that has not been used, `gawk` forces the variable to be a scalar. Other implementations of `awk` leave the variable without a type. Consider:

```
$ gawk 'BEGIN { print length(x) ; x[1] = 1 }'
⊣ 0
error gawk: fatal: attempt to use scalar ‘x’ as array

$ nawk 'BEGIN { print length(x) ; x[1] = 1 }'
⊣ 0
```

If `--lint` has been specified on the command line, `gawk` issues a warning about this.

With `gawk` and several other `awk` implementations, when given an array argument, the `length()` function returns the number of elements in the array. (c.e.) This is less useful than it might seem at first, as the array is not guaranteed to be indexed from one to the number of elements in it. If `--lint` is provided on the command line (see Section 2.2 [Command-Line Options], page 29), `gawk` warns that passing an array argument is not portable. If `--posix` is supplied, using an array argument is a fatal error (see Chapter 8 [Arrays in `awk`], page 145).

`match(string, regexp [, array])`

Search *string* for the longest, leftmost substring matched by the regular expression, *regexp* and return the character position, or *index*, at which that substring begins (one, if it starts at the beginning of *string*). If no match is found, return zero.

The *regexp* argument may be either a regexp constant (`/.../`) or a string constant (`"..."`). In the latter case, the string is treated as a regexp to be matched. See Section 3.8 [Using Dynamic Regexps], page 53, for a discussion of the difference between the two forms, and the implications for writing your program correctly.

The order of the first two arguments is backwards from most other string functions that work with regular expressions, such as `sub()` and `gsub()`. It might help to remember that for `match()`, the order is the same as for the '`~`' operator: '*`string ~ regexp`*'.

The `match()` function sets the built-in variable `RSTART` to the index. It also sets the built-in variable `RLENGTH` to the length in characters of the matched substring. If no match is found, `RSTART` is set to zero, and `RLENGTH` to −1.

For example:

```
{
        if ($1 == "FIND")
          regex = $2
        else {
          where = match($0, regex)
          if (where != 0)
            print "Match of", regex, "found at",
                        where, "in", $0
        }
}
```

This program looks for lines that match the regular expression stored in the variable `regex`. This regular expression can be changed. If the first word on a line is '`FIND`', `regex` is changed to be the second word on that line. Therefore, if given:

```
FIND ru+n
My program runs
but not very quickly
FIND Melvin
JF+KM
This line is property of Reality Engineering Co.
Melvin was here.
```

`awk` prints:

```
Match of ru+n found at 12 in My program runs
Match of Melvin found at 1 in Melvin was here.
```

If *array* is present, it is cleared, and then the zeroth element of *array* is set to the entire portion of *string* matched by *regexp*. If *regexp* contains parentheses, the integer-indexed elements of *array* are set to contain the portion of *string* matching the corresponding parenthesized subexpression. For example:

```
$ echo foooobazbarrrrr |
> gawk '{ match($0, /(fo+).+(bar*)/, arr)
>         print arr[1], arr[2] }'
⊣ foooo barrrrr
```

In addition, multidimensional subscripts are available providing the start index and length of each matched subexpression:

```
$ echo foooobazbarrrrr |
> gawk '{ match($0, /(fo+).+(bar*)/, arr)
>           print arr[1], arr[2]
>           print arr[1, "start"], arr[1, "length"]
>           print arr[2, "start"], arr[2, "length"]
> }'
⊣ foooo barrrrr
⊣ 1 5
⊣ 9 7
```

There may not be subscripts for the start and index for every parenthesized subexpression, since they may not all have matched text; thus they should be tested for with the `in` operator (see Section 8.1.2 [Referring to an Array Element], page 146).

The *array* argument to `match()` is a `gawk` extension. In compatibility mode (see Section 2.2 [Command-Line Options], page 29), using a third argument is a fatal error.

`patsplit(`*`string`*`, `*`array`* [`, `*`fieldpat`* [`, `*`seps`*]]`) #`

Divide *string* into pieces defined by *fieldpat* and store the pieces in *array* and the separator strings in the *seps* array. The first piece is stored in *`array`*`[1]`, the second piece in *`array`*`[2]`, and so forth. The third argument, *fieldpat*, is a regexp describing the fields in *string* (just as `FPAT` is a regexp describing the fields in input records). It may be either a regexp constant or a string. If *fieldpat* is omitted, the value of `FPAT` is used. `patsplit()` returns the number of elements created. *`seps`*`[`*`i`*`]` is the separator string between *`array`*`[`*`i`*`]` and *`array`*`[`*`i`*`+1]`. Any leading separator will be in *`seps`*`[0]`.

The `patsplit()` function splits strings into pieces in a manner similar to the way input lines are split into fields using `FPAT` (see Section 4.7 [Defining Fields By Content], page 69.

Before splitting the string, `patsplit()` deletes any previously existing elements in the arrays *array* and *seps*.

The `patsplit()` function is a `gawk` extension. In compatibility mode (see Section 2.2 [Command-Line Options], page 29), it is not available.

`split(`*`string`*`, `*`array`* [`, `*`fieldsep`* [`, `*`seps`*]]`)`

Divide *string* into pieces separated by *fieldsep* and store the pieces in *array* and the separator strings in the *seps* array. The first piece is stored in *`array`*`[1]`, the second piece in *`array`*`[2]`, and so forth. The string value of the third argument, *fieldsep*, is a regexp describing where to split *string* (much as `FS` can be a regexp describing where to split input records; see Section 4.5.2 [Using Regular Expressions to Separate Fields], page 63). If *fieldsep* is omitted, the value of `FS` is used. `split()` returns the number of elements created. *seps* is a `gawk` extension with *`seps`*`[`*`i`*`]` being the separator string between *`array`*`[`*`i`*`]` and *`array`*`[`*`i`*`+1]`. If *fieldsep* is a single space then any leading whitespace goes into *seps*[0] and any trailing whitespace goes into *seps*[*n*] where *n* is the return value of `split()` (that is, the number of elements in *array*).

The `split()` function splits strings into pieces in a manner similar to the way input lines are split into fields. For example:

```
split("cul-de-sac", a, "-", seps)
```

splits the string '`cul-de-sac`' into three fields using '`-`' as the separator. It sets the contents of the array `a` as follows:

```
a[1] = "cul"
a[2] = "de"
a[3] = "sac"
```

and sets the contents of the array `seps` as follows:

```
seps[1] = "-"
seps[2] = "-"
```

The value returned by this call to `split()` is three.

As with input field-splitting, when the value of *fieldsep* is `" "`, leading and trailing whitespace is ignored in values assigned to the elements of *array* but not in *seps*, and the elements are separated by runs of whitespace. Also as with input field-splitting, if *fieldsep* is the null string, each individual character in the string is split into its own array element. (c.e.)

Note, however, that `RS` has no effect on the way `split()` works. Even though '`RS = ""`' causes newline to also be an input field separator, this does not affect how `split()` splits strings.

Modern implementations of `awk`, including `gawk`, allow the third argument to be a regexp constant (`/abc/`) as well as a string. The POSIX standard allows this as well. See Section 3.8 [Using Dynamic Regexps], page 53, for a discussion of the difference between using a string constant or a regexp constant, and the implications for writing your program correctly.

Before splitting the string, `split()` deletes any previously existing elements in the arrays *array* and *seps*.

If *string* is null, the array has no elements. (So this is a portable way to delete an entire array with one statement. See Section 8.2 [The `delete` Statement], page 151.)

If *string* does not match *fieldsep* at all (but is not null), *array* has one element only. The value of that element is the original *string*.

`sprintf(`*`format`*`, `*`expression1`*`, ...)`

Return (without printing) the string that `printf` would have printed out with the same arguments (see Section 5.5 [Using `printf` Statements for Fancier Printing], page 84). For example:

```
pival = sprintf("pi = %.2f (approx.)", 22/7)
```

assigns the string '`pi = 3.14 (approx.)`' to the variable `pival`.

`strtonum(`*`str`*`) #`

Examine *str* and return its numeric value. If *str* begins with a leading '`0`', `strtonum()` assumes that *str* is an octal number. If *str* begins with a leading '0x' or '0X', `strtonum()` assumes that *str* is a hexadecimal number. For example:

```
$ echo 0x11 |
> gawk '{ printf "%d\n", strtonum($1) }'
⊣ 17
```

Using the `strtonum()` function is *not* the same as adding zero to a string value; the automatic coercion of strings to numbers works only for decimal data, not for octal or hexadecimal.[4]

Note also that `strtonum()` uses the current locale's decimal point for recognizing numbers (see Section 6.6 [Where You Are Makes A Difference], page 118).

`strtonum()` is a `gawk` extension; it is not available in compatibility mode (see Section 2.2 [Command-Line Options], page 29).

`sub(`*`regexp`*`, `*`replacement`* [`, `*`target`*]`)`

Search *target*, which is treated as a string, for the leftmost, longest substring matched by the regular expression *regexp*. Modify the entire string by replacing the matched text with *replacement*. The modified string becomes the new value of *target*. Return the number of substitutions made (zero or one).

The *regexp* argument may be either a regexp constant (`/.../`) or a string constant (`"..."`). In the latter case, the string is treated as a regexp to be matched. See Section 3.8 [Using Dynamic Regexps], page 53, for a discussion of the difference between the two forms, and the implications for writing your program correctly.

This function is peculiar because *target* is not simply used to compute a value, and not just any expression will do—it must be a variable, field, or array element so that `sub()` can store a modified value there. If this argument is omitted, then the default is to use and alter `$0`.[5] For example:

```
str = "water, water, everywhere"
sub(/at/, "ith", str)
```

sets `str` to '`wither, water, everywhere`', by replacing the leftmost longest occurrence of '`at`' with '`ith`'.

If the special character '`&`' appears in *replacement*, it stands for the precise substring that was matched by *regexp*. (If the regexp can match more than one string, then this precise substring may vary.) For example:

```
{ sub(/candidate/, "& and his wife"); print }
```

changes the first occurrence of '`candidate`' to '`candidate and his wife`' on each input line. Here is another example:

```
$ awk 'BEGIN {
>         str = "daabaaa"
>         sub(/a+/, "C&C", str)
```

---

[4] Unless you use the `--non-decimal-data` option, which isn't recommended. See Section 12.1 [Allowing Nondecimal Input Data], page 277, for more information.

[5] Note that this means that the record will first be regenerated using the value of `OFS` if any fields have been changed, and that the fields will be updated after the substitution, even if the operation is a "no-op" such as '`sub(/^/, "")`'.

```
>           print str
> }'
⊣ dCaaCbaaa
```

This shows how '&' can represent a nonconstant string and also illustrates the "leftmost, longest" rule in regexp matching (see Section 3.7 [How Much Text Matches?], page 52).

The effect of this special character ('&') can be turned off by putting a backslash before it in the string. As usual, to insert one backslash in the string, you must write two backslashes. Therefore, write '\\&' in a string constant to include a literal '&' in the replacement. For example, the following shows how to replace the first '|' on each line with an '&':

```
{ sub(/\|/, "\\&"); print }
```

As mentioned, the third argument to `sub()` must be a variable, field or array element. Some versions of `awk` allow the third argument to be an expression that is not an lvalue. In such a case, `sub()` still searches for the pattern and returns zero or one, but the result of the substitution (if any) is thrown away because there is no place to put it. Such versions of `awk` accept expressions like the following:

```
sub(/USA/, "United States", "the USA and Canada")
```

For historical compatibility, `gawk` accepts such erroneous code. However, using any other nonchangeable object as the third parameter causes a fatal error and your program will not run.

Finally, if the *regexp* is not a regexp constant, it is converted into a string, and then the value of that string is treated as the regexp to match.

`substr(`*string*`, `*start*` [, `*length*`])`

Return a *length*-character-long substring of *string*, starting at character number *start*. The first character of a string is character number one.[6] For example, `substr("washington", 5, 3)` returns `"ing"`.

If *length* is not present, `substr()` returns the whole suffix of *string* that begins at character number *start*. For example, `substr("washington", 5)` returns `"ington"`. The whole suffix is also returned if *length* is greater than the number of characters remaining in the string, counting from character *start*.

If *start* is less than one, `substr()` treats it as if it was one. (POSIX doesn't specify what to do in this case: Brian Kernighan's `awk` acts this way, and therefore `gawk` does too.) If *start* is greater than the number of characters in the string, `substr()` returns the null string. Similarly, if *length* is present but less than or equal to zero, the null string is returned.

The string returned by `substr()` *cannot* be assigned. Thus, it is a mistake to attempt to change a portion of a string, as shown in the following example:

```
string = "abcdef"
# try to get "abCDEf", won't work
substr(string, 3, 3) = "CDE"
```

It is also a mistake to use `substr()` as the third argument of `sub()` or `gsub()`:

[6] This is different from C and C++, in which the first character is number zero.

```
gsub(/xyz/, "pdq", substr($0, 5, 20))  # WRONG
```

(Some commercial versions of `awk` treat `substr()` as assignable, but doing so is not portable.)

If you need to replace bits and pieces of a string, combine `substr()` with string concatenation, in the following manner:

```
string = "abcdef"
...
string = substr(string, 1, 2) "CDE" substr(string, 6)
```

`tolower(`*string*`)`
Return a copy of *string*, with each uppercase character in the string replaced with its corresponding lowercase character. Nonalphabetic characters are left unchanged. For example, `tolower("MiXeD cAsE 123")` returns `"mixed case 123"`.

`toupper(`*string*`)`
Return a copy of *string*, with each lowercase character in the string replaced with its corresponding uppercase character. Nonalphabetic characters are left unchanged. For example, `toupper("MiXeD cAsE 123")` returns `"MIXED CASE 123"`.

9.1.3.1 More About '\' and '&' with sub(), gsub(), and gensub()

When using `sub()`, `gsub()`, or `gensub()`, and trying to get literal backslashes and ampersands into the replacement text, you need to remember that there are several levels of *escape processing* going on.

First, there is the *lexical* level, which is when `awk` reads your program and builds an internal copy of it that can be executed. Then there is the runtime level, which is when `awk` actually scans the replacement string to determine what to generate.

At both levels, `awk` looks for a defined set of characters that can come after a backslash. At the lexical level, it looks for the escape sequences listed in Section 3.2 [Escape Sequences], page 44. Thus, for every '\' that `awk` processes at the runtime level, you must type two backslashes at the lexical level. When a character that is not valid for an escape sequence follows the '\', Brian Kernighan's `awk` and `gawk` both simply remove the initial '\' and put the next character into the string. Thus, for example, `"a\qb"` is treated as `"aqb"`.

At the runtime level, the various functions handle sequences of '\' and '&' differently. The situation is (sadly) somewhat complex. Historically, the `sub()` and `gsub()` functions treated the two character sequence '\&' specially; this sequence was replaced in the generated text with a single '&'. Any other '\' within the *replacement* string that did not precede an '&' was passed through unchanged. This is illustrated in Table 9.1.

You type	`sub()` sees	`sub()` generates
`\&`	`&`	the matched text
`\\&`	`\&`	a literal ‘`&`’
`\\\&`	`\&`	a literal ‘`&`’
`\\\\&`	`\\&`	a literal ‘`\&`’
`\\\\\&`	`\\&`	a literal ‘`\&`’
`\\\\\\&`	`\\\&`	a literal ‘`\\&`’
`\\q`	`\q`	a literal ‘`\q`’

Table 9.1: Historical Escape Sequence Processing for `sub()` and `gsub()`

This table shows both the lexical-level processing, where an odd number of backslashes becomes an even number at the runtime level, as well as the runtime processing done by `sub()`. (For the sake of simplicity, the rest of the following tables only show the case of even numbers of backslashes entered at the lexical level.)

The problem with the historical approach is that there is no way to get a literal ‘`\`’ followed by the matched text.

The 1992 POSIX standard attempted to fix this problem. That standard says that `sub()` and `gsub()` look for either a ‘`\`’ or an ‘`&`’ after the ‘`\`’. If either one follows a ‘`\`’, that character is output literally. The interpretation of ‘`\`’ and ‘`&`’ then becomes as shown in Table 9.2.

You type	`sub()` sees	`sub()` generates
`&`	`&`	the matched text
`\\&`	`\&`	a literal ‘`&`’
`\\\\&`	`\\&`	a literal ‘`\`’, then the matched text
`\\\\\\&`	`\\\&`	a literal ‘`\&`’

Table 9.2: 1992 POSIX Rules for `sub()` and `gsub()` Escape Sequence Processing

This appears to solve the problem. Unfortunately, the phrasing of the standard is unusual. It says, in effect, that ‘`\`’ turns off the special meaning of any following character, but for anything other than ‘`\`’ and ‘`&`’, such special meaning is undefined. This wording leads to two problems:

- Backslashes must now be doubled in the *replacement* string, breaking historical `awk` programs.
- To make sure that an `awk` program is portable, *every* character in the *replacement* string must be preceded with a backslash.[7]

Because of the problems just listed, in 1996, the `gawk` maintainer submitted proposed text for a revised standard that reverts to rules that correspond more closely to the original

[7] This consequence was certainly unintended.

existing practice. The proposed rules have special cases that make it possible to produce a '\' preceding the matched text. This is shown in Table 9.3.

You type	`sub()` sees	`sub()` generates
`\\\\\\&`	`\\\&`	a literal '`\&`'
`\\\\&`	`\\&`	a literal '\', followed by the matched text
`\\&`	`\&`	a literal '`&`'
`\\q`	`\q`	a literal '`\q`'
`\\\\`	`\\`	`\\`

Table 9.3: Proposed Rules For `sub()` And Backslash

In a nutshell, at the runtime level, there are now three special sequences of characters ('`\\\&`', '`\\&`' and '`\&`') whereas historically there was only one. However, as in the historical case, any '\' that is not part of one of these three sequences is not special and appears in the output literally.

`gawk` 3.0 and 3.1 follow these proposed POSIX rules for `sub()` and `gsub()`. The POSIX standard took much longer to be revised than was expected in 1996. The 2001 standard does not follow the above rules. Instead, the rules there are somewhat simpler. The results are similar except for one case.

The POSIX rules state that '`\&`' in the replacement string produces a literal '`&`', '`\\`' produces a literal '\', and '\' followed by anything else is not special; the '\' is placed straight into the output. These rules are presented in Table 9.4.

You type	`sub()` sees	`sub()` generates
`\\\\\\&`	`\\\&`	a literal '`\&`'
`\\\\&`	`\\&`	a literal '\', followed by the matched text
`\\&`	`\&`	a literal '`&`'
`\\q`	`\q`	a literal '`\q`'
`\\\\`	`\\`	`\`

Table 9.4: POSIX Rules For `sub()` And `gsub()`

The only case where the difference is noticeable is the last one: '`\\\\`' is seen as '`\\`' and produces '`\`' instead of '`\\`'.

Starting with version 3.1.4, `gawk` followed the POSIX rules when `--posix` is specified (see Section 2.2 [Command-Line Options], page 29). Otherwise, it continued to follow the 1996 proposed rules, since that had been its behavior for many years.

When version 4.0.0 was released, the `gawk` maintainer made the POSIX rules the default, breaking well over a decade's worth of backwards compatibility.[8] Needless to say, this was

[8] This was rather naive of him, despite there being a note in this section indicating that the next major version would move to the POSIX rules.

a bad idea, and as of version 4.0.1, `gawk` resumed its historical behavior, and only follows the POSIX rules when `--posix` is given.

The rules for `gensub()` are considerably simpler. At the runtime level, whenever `gawk` sees a '\', if the following character is a digit, then the text that matched the corresponding parenthesized subexpression is placed in the generated output. Otherwise, no matter what character follows the '\', it appears in the generated text and the '\' does not, as shown in Table 9.5.

You type	`gensub()` sees	`gensub()` generates
`&`	`&`	the matched text
`\\&`	`\&`	a literal '`&`'
`\\\\`	`\\`	a literal '`\`'
`\\\\&`	`\\&`	a literal '`\`', then the matched text
`\\\\\\&`	`\\\&`	a literal '`\&`'
`\\q`	`\q`	a literal '`q`'

Table 9.5: Escape Sequence Processing For `gensub()`

Because of the complexity of the lexical and runtime level processing and the special cases for `sub()` and `gsub()`, we recommend the use of `gawk` and `gensub()` when you have to do substitutions.

Matching the Null String

In `awk`, the '`*`' operator can match the null string. This is particularly important for the `sub()`, `gsub()`, and `gensub()` functions. For example:

```
$ echo abc | awk '{ gsub(/m*/, "X"); print }'
⊣ XaXbXcX
```

Although this makes a certain amount of sense, it can be surprising.

9.1.4 Input/Output Functions

The following functions relate to input/output (I/O). Optional parameters are enclosed in square brackets ([ ]):

`close(`*filename* [`,` *how*]`)`

Close the file *filename* for input or output. Alternatively, the argument may be a shell command that was used for creating a coprocess, or for redirecting to or from a pipe; then the coprocess or pipe is closed. See Section 5.8 [Closing Input and Output Redirections], page 94, for more information.

When closing a coprocess, it is occasionally useful to first close one end of the two-way pipe and then to close the other. This is done by providing a second argument to `close()`. This second argument should be one of the two string values `"to"` or `"from"`, indicating which end of the pipe to close. Case in the string does not matter. See Section 12.3 [Two-Way Communications with

Another Process], page 283, which discusses this feature in more detail and gives an example.

`fflush([filename])`

Flush any buffered output associated with *filename*, which is either a file opened for writing or a shell command for redirecting output to a pipe or coprocess.

Many utility programs *buffer* their output; i.e., they save information to write to a disk file or the screen in memory until there is enough for it to be worthwhile to send the data to the output device. This is often more efficient than writing every little bit of information as soon as it is ready. However, sometimes it is necessary to force a program to *flush* its buffers; that is, write the information to its destination, even if a buffer is not full. This is the purpose of the `fflush()` function—`gawk` also buffers its output and the `fflush()` function forces `gawk` to flush its buffers.

`fflush()` was added to Brian Kernighan's version of `awk` in 1994. For over two decades, it was not part of the POSIX standard. As of December, 2012, it was accepted for inclusion into the POSIX standard. See the Austin Group website (`http://austingroupbugs.net/view.php?id=634`).

POSIX standardizes `fflush()` as follows: If there is no argument, or if the argument is the null string (`""`), then `awk` flushes the buffers for *all* open output files and pipes.

> **NOTE:** Prior to version 4.0.2, `gawk` would flush only the standard output if there was no argument, and flush all output files and pipes if the argument was the null string. This was changed in order to be compatible with Brian Kernighan's `awk`, in the hope that standardizing this feature in POSIX would then be easier (which indeed helped).
>
> With `gawk`, you can use '`fflush("/dev/stdout")`' if you wish to flush only the standard output.

`fflush()` returns zero if the buffer is successfully flushed; otherwise, it returns non-zero (`gawk` returns −1). In the case where all buffers are flushed, the return value is zero only if all buffers were flushed successfully. Otherwise, it is −1, and `gawk` warns about the problem *filename*.

`gawk` also issues a warning message if you attempt to flush a file or pipe that was opened for reading (such as with `getline`), or if *filename* is not an open file, pipe, or coprocess. In such a case, `fflush()` returns −1, as well.

`system(command)`

Execute the operating-system command *command* and then return to the `awk` program. Return *command*'s exit status.

For example, if the following fragment of code is put in your `awk` program:

```
END {
     system("date | mail -s 'awk run done' root")
}
```

the system administrator is sent mail when the `awk` program finishes processing input and begins its end-of-input processing.

Note that redirecting `print` or `printf` into a pipe is often enough to accomplish your task. If you need to run many commands, it is more efficient to simply print them down a pipeline to the shell:

```
while (more stuff to do)
    print command | "/bin/sh"
close("/bin/sh")
```

However, if your `awk` program is interactive, `system()` is useful for running large self-contained programs, such as a shell or an editor. Some operating systems cannot implement the `system()` function. `system()` causes a fatal error if it is not supported.

> **NOTE:** When `--sandbox` is specified, the `system()` function is disabled (see Section 2.2 [Command-Line Options], page 29).

Interactive Versus Noninteractive Buffering

As a side point, buffering issues can be even more confusing, depending upon whether your program is *interactive*, i.e., communicating with a user sitting at a keyboard.[9]

Interactive programs generally *line buffer* their output; i.e., they write out every line. Noninteractive programs wait until they have a full buffer, which may be many lines of output. Here is an example of the difference:

```
$ awk '{ print $1 + $2 }'
1 1
⊣ 2
2 3
⊣ 5
Ctrl-d
```

Each line of output is printed immediately. Compare that behavior with this example:

```
$ awk '{ print $1 + $2 }' | cat
1 1
2 3
Ctrl-d
⊣ 2
⊣ 5
```

Here, no output is printed until after the *Ctrl-d* is typed, because it is all buffered and sent down the pipe to `cat` in one shot.

[9] A program is interactive if the standard output is connected to a terminal device. On modern systems, this means your keyboard and screen.

Controlling Output Buffering with system()

The fflush() function provides explicit control over output buffering for individual files and pipes. However, its use is not portable to many older awk implementations. An alternative method to flush output buffers is to call system() with a null string as its argument:

```
system("")   # flush output
```

gawk treats this use of the system() function as a special case and is smart enough not to run a shell (or other command interpreter) with the empty command. Therefore, with gawk, this idiom is not only useful, it is also efficient. While this method should work with other awk implementations, it does not necessarily avoid starting an unnecessary shell. (Other implementations may only flush the buffer associated with the standard output and not necessarily all buffered output.)

If you think about what a programmer expects, it makes sense that system() should flush any pending output. The following program:

```
BEGIN {
     print "first print"
     system("echo system echo")
     print "second print"
}
```

must print:

```
first print
system echo
second print
```

and not:

```
system echo
first print
second print
```

If awk did not flush its buffers before calling system(), you would see the latter (undesirable) output.

9.1.5 Time Functions

awk programs are commonly used to process log files containing timestamp information, indicating when a particular log record was written. Many programs log their timestamp in the form returned by the time() system call, which is the number of seconds since a particular epoch. On POSIX-compliant systems, it is the number of seconds since 1970-01-01 00:00:00 UTC, not counting leap seconds.[10] All known POSIX-compliant systems support timestamps from 0 through $2^{31} - 1$, which is sufficient to represent times through 2038-01-19 03:14:07 UTC. Many systems support a wider range of timestamps, including negative timestamps that represent times before the epoch.

In order to make it easier to process such log files and to produce useful reports, gawk provides the following functions for working with timestamps. They are gawk extensions;

[10] See [Glossary], page 429, especially the entries "Epoch" and "UTC."

they are not specified in the POSIX standard.[11] However, recent versions of `mawk` (see Section B.5 [Other Freely Available `awk` Implementations], page 412) also support these functions. Optional parameters are enclosed in square brackets ([ ]):

`mktime(`*datespec*`)`
: Turn *datespec* into a timestamp in the same form as is returned by `systime()`. It is similar to the function of the same name in ISO C. The argument, *datespec*, is a string of the form `"`*YYYY MM DD HH MM SS* `[`*DST*`]"`. The string consists of six or seven numbers representing, respectively, the full year including century, the month from 1 to 12, the day of the month from 1 to 31, the hour of the day from 0 to 23, the minute from 0 to 59, the second from 0 to 60,[12] and an optional daylight-savings flag.

  The values of these numbers need not be within the ranges specified; for example, an hour of −1 means 1 hour before midnight. The origin-zero Gregorian calendar is assumed, with year 0 preceding year 1 and year −1 preceding year 0. The time is assumed to be in the local timezone. If the daylight-savings flag is positive, the time is assumed to be daylight savings time; if zero, the time is assumed to be standard time; and if negative (the default), `mktime()` attempts to determine whether daylight savings time is in effect for the specified time.

  If *datespec* does not contain enough elements or if the resulting time is out of range, `mktime()` returns −1.

`strftime(`[*format* [`,` *timestamp* [`,` *utc-flag*]]]`)`
: Format the time specified by *timestamp* based on the contents of the *format* string and return the result. It is similar to the function of the same name in ISO C. If *utc-flag* is present and is either nonzero or non-null, the value is formatted as UTC (Coordinated Universal Time, formerly GMT or Greenwich Mean Time). Otherwise, the value is formatted for the local time zone. The *timestamp* is in the same format as the value returned by the `systime()` function. If no *timestamp* argument is supplied, `gawk` uses the current time of day as the timestamp. If no *format* argument is supplied, `strftime()` uses the value of `PROCINFO["strftime"]` as the format string (see Section 7.5 [Built-in Variables], page 134). The default string value is `"%a %b %e %H:%M:%S %Z %Y"`. This format string produces output that is equivalent to that of the `date` utility. You can assign a new value to `PROCINFO["strftime"]` to change the default format.

`systime()`
: Return the current time as the number of seconds since the system epoch. On POSIX systems, this is the number of seconds since 1970-01-01 00:00:00 UTC, not counting leap seconds. It may be a different number on other systems.

The `systime()` function allows you to compare a timestamp from a log file with the current time of day. In particular, it is easy to determine how long ago a particular record was logged. It also allows you to produce log records using the “seconds since the epoch” format.

---

[11] The GNU `date` utility can also do many of the things described here. Its use may be preferable for simple time-related operations in shell scripts.

[12] Occasionally there are minutes in a year with a leap second, which is why the seconds can go up to 60.

The `mktime()` function allows you to convert a textual representation of a date and time into a timestamp. This makes it easy to do before/after comparisons of dates and times, particularly when dealing with date and time data coming from an external source, such as a log file.

The `strftime()` function allows you to easily turn a timestamp into human-readable information. It is similar in nature to the `sprintf()` function (see Section 9.1.3 [String-Manipulation Functions], page 161), in that it copies nonformat specification characters verbatim to the returned string, while substituting date and time values for format specifications in the *format* string.

`strftime()` is guaranteed by the 1999 ISO C standard[13] to support the following date format specifications:

`%a` The locale's abbreviated weekday name.

`%A` The locale's full weekday name.

`%b` The locale's abbreviated month name.

`%B` The locale's full month name.

`%c` The locale's "appropriate" date and time representation. (This is '`%A %B %d %T %Y`' in the `"C"` locale.)

`%C` The century part of the current year. This is the year divided by 100 and truncated to the next lower integer.

`%d` The day of the month as a decimal number (01–31).

`%D` Equivalent to specifying '`%m/%d/%y`'.

`%e` The day of the month, padded with a space if it is only one digit.

`%F` Equivalent to specifying '`%Y-%m-%d`'. This is the ISO 8601 date format.

`%g` The year modulo 100 of the ISO 8601 week number, as a decimal number (00–99). For example, January 1, 1993 is in week 53 of 1992. Thus, the year of its ISO 8601 week number is 1992, even though its year is 1993. Similarly, December 31, 1973 is in week 1 of 1974. Thus, the year of its ISO week number is 1974, even though its year is 1973.

`%G` The full year of the ISO week number, as a decimal number.

`%h` Equivalent to '`%b`'.

`%H` The hour (24-hour clock) as a decimal number (00–23).

`%I` The hour (12-hour clock) as a decimal number (01–12).

`%j` The day of the year as a decimal number (001–366).

`%m` The month as a decimal number (01–12).

`%M` The minute as a decimal number (00–59).

`%n` A newline character (ASCII LF).

[13] Unfortunately, not every system's `strftime()` necessarily supports all of the conversions listed here.

`%p` The locale's equivalent of the AM/PM designations associated with a 12-hour clock.

`%r` The locale's 12-hour clock time. (This is '`%I:%M:%S %p`' in the `"C"` locale.)

`%R` Equivalent to specifying '`%H:%M`'.

`%S` The second as a decimal number (00–60).

`%t` A TAB character.

`%T` Equivalent to specifying '`%H:%M:%S`'.

`%u` The weekday as a decimal number (1–7). Monday is day one.

`%U` The week number of the year (the first Sunday as the first day of week one) as a decimal number (00–53).

`%V` The week number of the year (the first Monday as the first day of week one) as a decimal number (01–53). The method for determining the week number is as specified by ISO 8601. (To wit: if the week containing January 1 has four or more days in the new year, then it is week one; otherwise it is week 53 of the previous year and the next week is week one.)

`%w` The weekday as a decimal number (0–6). Sunday is day zero.

`%W` The week number of the year (the first Monday as the first day of week one) as a decimal number (00–53).

`%x` The locale's "appropriate" date representation. (This is '`%A %B %d %Y`' in the `"C"` locale.)

`%X` The locale's "appropriate" time representation. (This is '`%T`' in the `"C"` locale.)

`%y` The year modulo 100 as a decimal number (00–99).

`%Y` The full year as a decimal number (e.g., 2011).

`%z` The timezone offset in a +HHMM format (e.g., the format necessary to produce RFC 822/RFC 1036 date headers).

`%Z` The time zone name or abbreviation; no characters if no time zone is determinable.

`%Ec %EC %Ex %EX %Ey %EY %Od %Oe %OH`
`%OI %Om %OM %OS %Ou %OU %OV %Ow %OW %Oy`
"Alternate representations" for the specifications that use only the second letter ('`%c`', '`%C`', and so on).[14] (These facilitate compliance with the POSIX `date` utility.)

`%%` A literal '`%`'.

[14] If you don't understand any of this, don't worry about it; these facilities are meant to make it easier to "internationalize" programs. Other internationalization features are described in Chapter 13 [Internationalization with `gawk`], page 291.

If a conversion specifier is not one of the above, the behavior is undefined.[15]

Informally, a *locale* is the geographic place in which a program is meant to run. For example, a common way to abbreviate the date September 4, 2012 in the United States is "9/4/12." In many countries in Europe, however, it is abbreviated "4.9.12." Thus, the '`%x`' specification in a `"US"` locale might produce '`9/4/12`', while in a `"EUROPE"` locale, it might produce '`4.9.12`'. The ISO C standard defines a default `"C"` locale, which is an environment that is typical of what many C programmers are used to.

For systems that are not yet fully standards-compliant, `gawk` supplies a copy of `strftime()` from the GNU C Library. It supports all of the just-listed format specifications. If that version is used to compile `gawk` (see Appendix B [Installing gawk], page 399), then the following additional format specifications are available:

`%k` The hour (24-hour clock) as a decimal number (0–23). Single-digit numbers are padded with a space.

`%l` The hour (12-hour clock) as a decimal number (1–12). Single-digit numbers are padded with a space.

`%s` The time as a decimal timestamp in seconds since the epoch.

Additionally, the alternate representations are recognized but their normal representations are used.

The following example is an `awk` implementation of the POSIX `date` utility. Normally, the `date` utility prints the current date and time of day in a well-known format. However, if you provide an argument to it that begins with a '`+`', `date` copies nonformat specifier characters to the standard output and interprets the current time according to the format specifiers in the string. For example:

```
$ date '+Today is %A, %B %d, %Y.'
⊣ Today is Wednesday, March 30, 2011.
```

Here is the `gawk` version of the `date` utility. It has a shell "wrapper" to handle the `-u` option, which requires that `date` run as if the time zone is set to UTC:

```
#! /bin/sh
#
# date --- approximate the POSIX 'date' command

case $1 in
-u)  TZ=UTC0     # use UTC
     export TZ
     shift ;;
esac

gawk 'BEGIN  {
    format = "%a %b %e %H:%M:%S %Z %Y"
    exitval = 0
```

[15] This is because ISO C leaves the behavior of the C version of `strftime()` undefined and `gawk` uses the system's version of `strftime()` if it's there. Typically, the conversion specifier either does not appear in the returned string or appears literally.

```
        if (ARGC > 2)
            exitval = 1
        else if (ARGC == 2) {
            format = ARGV[1]
            if (format ~ /^\+/)
                format = substr(format, 2)   # remove leading +
        }
        print strftime(format)
        exit exitval
    }' "$@"
```

9.1.6 Bit-Manipulation Functions

I can explain it for you, but I can't understand it for you.
Anonymous

Many languages provide the ability to perform *bitwise* operations on two integer numbers. In other words, the operation is performed on each successive pair of bits in the operands. Three common operations are bitwise AND, OR, and XOR. The operations are described in Table 9.6.

	Bit operator					
	AND		OR		XOR	
Operands	0	1	0	1	0	1
0	0	0	0	1	0	1
1	0	1	1	1	1	0

Table 9.6: Bitwise Operations

As you can see, the result of an AND operation is 1 only when *both* bits are 1. The result of an OR operation is 1 if *either* bit is 1. The result of an XOR operation is 1 if either bit is 1, but not both. The next operation is the *complement*; the complement of 1 is 0 and the complement of 0 is 1. Thus, this operation "flips" all the bits of a given value.

Finally, two other common operations are to shift the bits left or right. For example, if you have a bit string '`10111001`' and you shift it right by three bits, you end up with '`00010111`'.[16] If you start over again with '`10111001`' and shift it left by three bits, you end up with '`11001000`'. `gawk` provides built-in functions that implement the bitwise operations just described. They are:

`and(`*`v1`*`, `*`v2`* [`, `...])
: Return the bitwise AND of the arguments. There must be at least two.

`compl(`*`val`*`)`
: Return the bitwise complement of *val*.

`lshift(`*`val`*`, `*`count`*`)`
: Return the value of *val*, shifted left by *count* bits.

[16] This example shows that 0's come in on the left side. For `gawk`, this is always true, but in some languages, it's possible to have the left side fill with 1's. Caveat emptor.

`or(`*v1*`, `*v2* [`, `...])
: Return the bitwise OR of the arguments. There must be at least two.

`rshift(`*val*`, `*count*`)`
: Return the value of *val*, shifted right by *count* bits.

`xor(`*v1*`, `*v2* [`, `...])
: Return the bitwise XOR of the arguments. There must be at least two.

For all of these functions, first the double precision floating-point value is converted to the widest C unsigned integer type, then the bitwise operation is performed. If the result cannot be represented exactly as a C `double`, leading nonzero bits are removed one by one until it can be represented exactly. The result is then converted back into a C `double`. (If you don't understand this paragraph, don't worry about it.)

Here is a user-defined function (see Section 9.2 [User-Defined Functions], page 184) that illustrates the use of these functions:

```
# bits2str --- turn a byte into readable 1's and 0's

function bits2str(bits,        data, mask)
{
    if (bits == 0)
        return "0"

    mask = 1
    for (; bits != 0; bits = rshift(bits, 1))
        data = (and(bits, mask) ? "1" : "0") data

    while ((length(data) % 8) != 0)
        data = "0" data

    return data
}

BEGIN {
    printf "123 = %s\n", bits2str(123)
    printf "0123 = %s\n", bits2str(0123)
    printf "0x99 = %s\n", bits2str(0x99)
    comp = compl(0x99)
    printf "compl(0x99) = %#x = %s\n", comp, bits2str(comp)
    shift = lshift(0x99, 2)
    printf "lshift(0x99, 2) = %#x = %s\n", shift, bits2str(shift)
    shift = rshift(0x99, 2)
    printf "rshift(0x99, 2) = %#x = %s\n", shift, bits2str(shift)
}
```

This program produces the following output when run:

```
$ gawk -f testbits.awk
⊣ 123 = 01111011
⊣ 0123 = 01010011
```

```
⊣ 0x99 = 10011001
⊣ compl(0x99) = 0xffffff66 = 11111111111111111111111101100110
⊣ lshift(0x99, 2) = 0x264 = 0000001001100100
⊣ rshift(0x99, 2) = 0x26 = 00100110
```

The `bits2str()` function turns a binary number into a string. The number `1` represents a binary value where the rightmost bit is set to 1. Using this mask, the function repeatedly checks the rightmost bit. ANDing the mask with the value indicates whether the rightmost bit is 1 or not. If so, a `"1"` is concatenated onto the front of the string. Otherwise, a `"0"` is added. The value is then shifted right by one bit and the loop continues until there are no more 1 bits.

If the initial value is zero it returns a simple `"0"`. Otherwise, at the end, it pads the value with zeros to represent multiples of 8-bit quantities. This is typical in modern computers.

The main code in the `BEGIN` rule shows the difference between the decimal and octal values for the same numbers (see Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97), and then demonstrates the results of the `compl()`, `lshift()`, and `rshift()` functions.

9.1.7 Getting Type Information

`gawk` provides a single function that lets you distinguish an array from a scalar variable. This is necessary for writing code that traverses every element of a true multidimensional array (see Section 8.6 [Arrays of Arrays], page 156).

`isarray(`*x*`)`
: Return a true value if *x* is an array. Otherwise return false.

`isarray()` is meant for use in two circumstances. The first is when traversing a multidimensional array: you can test if an element is itself an array or not. The second is inside the body of a user-defined function (not discussed yet; see Section 9.2 [User-Defined Functions], page 184), to test if a paramater is an array or not.

Note, however, that using `isarray()` at the global level to test variables makes no sense. Since you are the one writing the program, you are supposed to know if your variables are arrays or not. And in fact, due to the way `gawk` works, if you pass the name of a variable that has not been previously used to `isarray()`, `gawk` will end up turning it into a scalar.

9.1.8 String-Translation Functions

`gawk` provides facilities for internationalizing `awk` programs. These include the functions described in the following list. The descriptions here are purposely brief. See Chapter 13 [Internationalization with `gawk`], page 291, for the full story. Optional parameters are enclosed in square brackets ([ ]):

`bindtextdomain(`*directory* [`,` *domain*]`)`
: Set the directory in which `gawk` will look for message translation files, in case they will not or cannot be placed in the "standard" locations (e.g., during testing). It returns the directory in which *domain* is "bound."

  The default *domain* is the value of `TEXTDOMAIN`. If *directory* is the null string (`""`), then `bindtextdomain()` returns the current binding for the given *domain*.

`dcgettext(`*`string`* [`,` *`domain`* [`,` *`category`*]]`)`
: Return the translation of *string* in text domain *domain* for locale category *category*. The default value for *domain* is the current value of `TEXTDOMAIN`. The default value for *category* is `"LC_MESSAGES"`.

`dcngettext(`*`string1`*`,` *`string2`*`,` *`number`* [`,` *`domain`* [`,` *`category`*]]`)`
: Return the plural form used for *number* of the translation of *string1* and *string2* in text domain *domain* for locale category *category*. *string1* is the English singular variant of a message, and *string2* the English plural variant of the same message. The default value for *domain* is the current value of `TEXTDOMAIN`. The default value for *category* is `"LC_MESSAGES"`.

9.2 User-Defined Functions

Complicated `awk` programs can often be simplified by defining your own functions. User-defined functions can be called just like built-in ones (see Section 6.4 [Function Calls], page 115), but it is up to you to define them, i.e., to tell `awk` what they should do.

9.2.1 Function Definition Syntax

Definitions of functions can appear anywhere between the rules of an `awk` program. Thus, the general form of an `awk` program is extended to include sequences of rules *and* user-defined function definitions. There is no need to put the definition of a function before all uses of the function. This is because `awk` reads the entire program before starting to execute any of it.

The definition of a function named *name* looks like this:

```
function name([parameter-list])
{
     body-of-function
}
```

Here, *name* is the name of the function to define. A valid function name is like a valid variable name: a sequence of letters, digits, and underscores that doesn't start with a digit. Within a single `awk` program, any particular name can only be used as a variable, array, or function.

parameter-list is an optional list of the function's arguments and local variable names, separated by commas. When the function is called, the argument names are used to hold the argument values given in the call. The local variables are initialized to the empty string. A function cannot have two parameters with the same name, nor may it have a parameter with the same name as the function itself.

In addition, according to the POSIX standard, function parameters cannot have the same name as one of the special built-in variables (see Section 7.5 [Built-in Variables], page 134. Not all versions of `awk` enforce this restriction.

The *body-of-function* consists of `awk` statements. It is the most important part of the definition, because it says what the function should actually *do*. The argument names exist to give the body a way to talk about the arguments; local variables exist to give the body places to keep temporary values.

Argument names are not distinguished syntactically from local variable names. Instead, the number of arguments supplied when the function is called determines how many argument variables there are. Thus, if three argument values are given, the first three names in *parameter-list* are arguments and the rest are local variables.

It follows that if the number of arguments is not the same in all calls to the function, some of the names in *parameter-list* may be arguments on some occasions and local variables on others. Another way to think of this is that omitted arguments default to the null string.

Usually when you write a function, you know how many names you intend to use for arguments and how many you intend to use as local variables. It is conventional to place some extra space between the arguments and the local variables, in order to document how your function is supposed to be used.

During execution of the function body, the arguments and local variable values hide, or *shadow*, any variables of the same names used in the rest of the program. The shadowed variables are not accessible in the function definition, because there is no way to name them while their names have been taken away for the local variables. All other variables used in the `awk` program can be referenced or set normally in the function's body.

The arguments and local variables last only as long as the function body is executing. Once the body finishes, you can once again access the variables that were shadowed while the function was running.

The function body can contain expressions that call functions. They can even call this function, either directly or by way of another function. When this happens, we say the function is *recursive*. The act of a function calling itself is called *recursion*.

All the built-in functions return a value to their caller. User-defined functions can do also, using the `return` statement, which is described in detail in Section 9.2.4 [The `return` Statement], page 191. Many of the subsequent examples in this section use the `return` statement.

In many `awk` implementations, including `gawk`, the keyword `function` may be abbreviated `func`. (c.e.) However, POSIX only specifies the use of the keyword `function`. This actually has some practical implications. If `gawk` is in POSIX-compatibility mode (see Section 2.2 [Command-Line Options], page 29), then the following statement does *not* define a function:

```
func foo() { a = sqrt($1) ; print a }
```

Instead it defines a rule that, for each record, concatenates the value of the variable '`func`' with the return value of the function '`foo`'. If the resulting string is non-null, the action is executed. This is probably not what is desired. (`awk` accepts this input as syntactically valid, because functions may be used before they are defined in `awk` programs.[17])

To ensure that your `awk` programs are portable, always use the keyword `function` when defining a function.

9.2.2 Function Definition Examples

Here is an example of a user-defined function, called `myprint()`, that takes a number and prints it in a specific format:

---

[17] This program won't actually run, since `foo()` is undefined.

```
function myprint(num)
{
     printf "%6.3g\n", num
}
```

To illustrate, here is an `awk` rule that uses our `myprint` function:

```
$3 > 0     { myprint($3) }
```

This program prints, in our special format, all the third fields that contain a positive number in our input. Therefore, when given the following input:

```
 1.2   3.4    5.6   7.8
 9.10 11.12 -13.14 15.16
17.18 19.20  21.22 23.24
```

this program, using our function to format the results, prints:

```
   5.6
  21.2
```

This function deletes all the elements in an array:

```
function delarray(a,    i)
{
    for (i in a)
       delete a[i]
}
```

When working with arrays, it is often necessary to delete all the elements in an array and start over with a new list of elements (see Section 8.2 [The `delete` Statement], page 151). Instead of having to repeat this loop everywhere that you need to clear out an array, your program can just call `delarray`. (This guarantees portability. The use of '`delete` *`array`*' to delete the contents of an entire array is a nonstandard extension.)

The following is an example of a recursive function. It takes a string as an input parameter and returns the string in backwards order. Recursive functions must always have a test that stops the recursion. In this case, the recursion terminates when the starting position is zero, i.e., when there are no more characters left in the string.

```
function rev(str, start)
{
    if (start == 0)
        return ""

    return (substr(str, start, 1) rev(str, start - 1))
}
```

If this function is in a file named `rev.awk`, it can be tested this way:

```
$ echo "Don't Panic!" |
> gawk --source '{ print rev($0, length($0)) }' -f rev.awk
⊣ !cinaP t'noD
```

The C `ctime()` function takes a timestamp and returns it in a string, formatted in a well-known fashion. The following example uses the built-in `strftime()` function (see Section 9.1.5 [Time Functions], page 176) to create an `awk` version of `ctime()`:

```
# ctime.awk
#
# awk version of C ctime(3) function

function ctime(ts,    format)
{
    format = "%a %b %e %H:%M:%S %Z %Y"
    if (ts == 0)
        ts = systime()       # use current time as default
    return strftime(format, ts)
}
```

9.2.3 Calling User-Defined Functions

This section describes how to call a user-defined function.

9.2.3.1 Writing A Function Call

Calling a function means causing the function to run and do its job. A function call is an expression and its value is the value returned by the function.

A function call consists of the function name followed by the arguments in parentheses. `awk` expressions are what you write in the call for the arguments. Each time the call is executed, these expressions are evaluated, and the values become the actual arguments. For example, here is a call to `foo()` with three arguments (the first being a string concatenation):

```
foo(x y, "lose", 4 * z)
```

CAUTION: Whitespace characters (spaces and TABs) are not allowed between the function name and the open-parenthesis of the argument list. If you write whitespace by mistake, `awk` might think that you mean to concatenate a variable with an expression in parentheses. However, it notices that you used a function name and not a variable name, and reports an error.

9.2.3.2 Controlling Variable Scope

There is no way to make a variable local to a `{ ... }` block in `awk`, but you can make a variable local to a function. It is good practice to do so whenever a variable is needed only in that function.

To make a variable local to a function, simply declare the variable as an argument after the actual function arguments (see Section 9.2.1 [Function Definition Syntax], page 184). Look at the following example where variable `i` is a global variable used by both functions `foo()` and `bar()`:

```
function bar()
{
    for (i = 0; i < 3; i++)
        print "bar's i=" i
}

function foo(j)
{
```

```
    i = j + 1
    print "foo's i=" i
    bar()
    print "foo's i=" i
}

BEGIN {
      i = 10
      print "top's i=" i
      foo(0)
      print "top's i=" i
}
```

Running this script produces the following, because the `i` in functions `foo()` and `bar()` and at the top level refer to the same variable instance:

```
top's i=10
foo's i=1
bar's i=0
bar's i=1
bar's i=2
foo's i=3
top's i=3
```

If you want `i` to be local to both `foo()` and `bar()` do as follows (the extra-space before `i` is a coding convention to indicate that `i` is a local variable, not an argument):

```
function bar(    i)
{
    for (i = 0; i < 3; i++)
        print "bar's i=" i
}

function foo(j,    i)
{
    i = j + 1
    print "foo's i=" i
    bar()
    print "foo's i=" i
}

BEGIN {
      i = 10
      print "top's i=" i
      foo(0)
      print "top's i=" i
}
```

Running the corrected script produces the following:

```
top's i=10
```

```
foo's i=1
bar's i=0
bar's i=1
bar's i=2
foo's i=1
top's i=10
```

Besides scalar values (strings and numbers), you may also have local arrays. By using a parameter name as an array, `awk` treats it as an array, and it is local to the function. In addition, recursive calls create new arrays. Consider this example:

```
function some_func(p1,      a)
{
    if (p1++ > 3)
        return

    a[p1] = p1

    some_func(p1)

    printf("At level %d, index %d %s found in a\n",
         p1, (p1 - 1), (p1 - 1) in a ? "is" : "is not")
    printf("At level %d, index %d %s found in a\n",
         p1, p1, p1 in a ? "is" : "is not")
    print ""
}

BEGIN {
    some_func(1)
}
```

When run, this program produces the following output:

```
At level 4, index 3 is not found in a
At level 4, index 4 is found in a

At level 3, index 2 is not found in a
At level 3, index 3 is found in a

At level 2, index 1 is not found in a
At level 2, index 2 is found in a
```

9.2.3.3 Passing Function Arguments By Value Or By Reference

In `awk`, when you declare a function, there is no way to declare explicitly whether the arguments are passed *by value* or *by reference*.

Instead the passing convention is determined at runtime when the function is called according to the following rule:

- If the argument is an array variable, then it is passed by reference,
- Otherwise the argument is passed by value.

Passing an argument by value means that when a function is called, it is given a *copy* of the value of this argument. The caller may use a variable as the expression for the argument, but the called function does not know this—it only knows what value the argument had. For example, if you write the following code:

```
foo = "bar"
z = myfunc(foo)
```

then you should not think of the argument to `myfunc()` as being "the variable `foo`." Instead, think of the argument as the string value `"bar"`. If the function `myfunc()` alters the values of its local variables, this has no effect on any other variables. Thus, if `myfunc()` does this:

```
function myfunc(str)
{
   print str
   str = "zzz"
   print str
}
```

to change its first argument variable `str`, it does *not* change the value of `foo` in the caller. The role of `foo` in calling `myfunc()` ended when its value (`"bar"`) was computed. If `str` also exists outside of `myfunc()`, the function body cannot alter this outer value, because it is shadowed during the execution of `myfunc()` and cannot be seen or changed from there.

However, when arrays are the parameters to functions, they are *not* copied. Instead, the array itself is made available for direct manipulation by the function. This is usually termed *call by reference*. Changes made to an array parameter inside the body of a function *are* visible outside that function.

> **NOTE:** Changing an array parameter inside a function can be very dangerous if you do not watch what you are doing. For example:
>
> ```
> function changeit(array, ind, nvalue)
> {
>      array[ind] = nvalue
> }
>
> BEGIN {
>     a[1] = 1; a[2] = 2; a[3] = 3
>     changeit(a, 2, "two")
>     printf "a[1] = %s, a[2] = %s, a[3] = %s\n",
>             a[1], a[2], a[3]
> }
> ```
>
> prints '`a[1] = 1, a[2] = two, a[3] = 3`', because `changeit` stores `"two"` in the second element of `a`.

Some `awk` implementations allow you to call a function that has not been defined. They only report a problem at runtime when the program actually tries to call the function. For example:

```
BEGIN {
    if (0)
        foo()
    else
```

```
            bar()
    }
    function bar() { ... }
    # note that ‘foo’ is not defined
```

Because the ‘if’ statement will never be true, it is not really a problem that foo() has not been defined. Usually, though, it is a problem if a program calls an undefined function.

If --lint is specified (see Section 2.2 [Command-Line Options], page 29), gawk reports calls to undefined functions.

Some awk implementations generate a runtime error if you use either the next statement or the nextfile statement (see Section 7.4.8 [The next Statement], page 132, also see Section 7.4.9 [The nextfile Statement], page 133) inside a user-defined function. gawk does not have this limitation.

9.2.4 The return Statement

As seen in several earlier examples, the body of a user-defined function can contain a return statement. This statement returns control to the calling part of the awk program. It can also be used to return a value for use in the rest of the awk program. It looks like this:

```
return [expression]
```

The *expression* part is optional. Due most likely to an oversight, POSIX does not define what the return value is if you omit the *expression*. Technically speaking, this make the returned value undefined, and therefore, unpredictable. In practice, though, all versions of awk simply return the null string, which acts like zero if used in a numeric context.

A return statement with no value expression is assumed at the end of every function definition. So if control reaches the end of the function body, then technically, the function returns an unpredictable value. In practice, it returns the empty string. awk does *not* warn you if you use the return value of such a function.

Sometimes, you want to write a function for what it does, not for what it returns. Such a function corresponds to a void function in C, C++ or Java, or to a procedure in Ada. Thus, it may be appropriate to not return any value; simply bear in mind that you should not be using the return value of such a function.

The following is an example of a user-defined function that returns a value for the largest number among the elements of an array:

```
function maxelt(vec,   i, ret)
{
     for (i in vec) {
          if (ret == "" || vec[i] > ret)
               ret = vec[i]
     }
     return ret
}
```

You call maxelt() with one argument, which is an array name. The local variables i and ret are not intended to be arguments; while there is nothing to stop you from passing more than one argument to maxelt(), the results would be strange. The extra space before i in the function parameter list indicates that i and ret are local variables. You should follow this convention when defining functions.

The following program uses the `maxelt()` function. It loads an array, calls `maxelt()`, and then reports the maximum number in that array:

```
function maxelt(vec,   i, ret)
{
     for (i in vec) {
          if (ret == "" || vec[i] > ret)
               ret = vec[i]
     }
     return ret
}

# Load all fields of each record into nums.
{
     for(i = 1; i <= NF; i++)
          nums[NR, i] = $i
}

END {
     print maxelt(nums)
}
```

Given the following input:

```
 1 5 23 8 16
44 3 5 2 8 26
256 291 1396 2962 100
-6 467 998 1101
99385 11 0 225
```

the program reports (predictably) that 99,385 is the largest value in the array.

9.2.5 Functions and Their Effects on Variable Typing

`awk` is a very fluid language. It is possible that `awk` can't tell if an identifier represents a scalar variable or an array until runtime. Here is an annotated sample program:

```
function foo(a)
{
    a[1] = 1   # parameter is an array
}

BEGIN {
    b = 1
    foo(b)  # invalid: fatal type mismatch

    foo(x)  # x uninitialized, becomes an array dynamically
    x = 1   # now not allowed, runtime error
}
```

In this example, the first call to `foo()` generates a fatal error, so `gawk` will not report the second error. If you comment out that call, though, then `gawk` will report the second error.

Usually, such things aren't a big issue, but it's worth being aware of them.

9.3 Indirect Function Calls

This section describes a gawk-specific extension.

Often, you may wish to defer the choice of function to call until runtime. For example, you may have different kinds of records, each of which should be processed differently.

Normally, you would have to use a series of if-else statements to decide which function to call. By using *indirect* function calls, you can specify the name of the function to call as a string variable, and then call the function. Let's look at an example.

Suppose you have a file with your test scores for the classes you are taking. The first field is the class name. The following fields are the functions to call to process the data, up to a "marker" field 'data:'. Following the marker, to the end of the record, are the various numeric test scores.

Here is the initial file; you wish to get the sum and the average of your test scores:

```
Biology_101 sum average data: 87.0 92.4 78.5 94.9
Chemistry_305 sum average data: 75.2 98.3 94.7 88.2
English_401 sum average data: 100.0 95.6 87.1 93.4
```

To process the data, you might write initially:

```
{
    class = $1
    for (i = 2; $i != "data:"; i++) {
        if ($i == "sum")
            sum()   # processes the whole record
        else if ($i == "average")
            average()
        ...           # and so on
    }
}
```

This style of programming works, but can be awkward. With *indirect* function calls, you tell gawk to use the *value* of a variable as the name of the function to call.

The syntax is similar to that of a regular function call: an identifier immediately followed by a left parenthesis, any arguments, and then a closing right parenthesis, with the addition of a leading '@' character:

```
the_func = "sum"
result = @the_func()   # calls the 'sum' function
```

Here is a full program that processes the previously shown data, using indirect function calls.

```
# indirectcall.awk --- Demonstrate indirect function calls

# average --- return the average of the values in fields $first - $last

function average(first, last,   sum, i)
{
    sum = 0;
```

```
    for (i = first; i <= last; i++)
        sum += $i

    return sum / (last - first + 1)
}

# sum --- return the sum of the values in fields $first - $last

function sum(first, last,   ret, i)
{
    ret = 0;
    for (i = first; i <= last; i++)
        ret += $i

    return ret
}
```

These two functions expect to work on fields; thus the parameters `first` and `last` indicate where in the fields to start and end. Otherwise they perform the expected computations and are not unusual.

```
# For each record, print the class name and the requested statistics

{
    class_name = $1
    gsub(/_/, " ", class_name)  # Replace _ with spaces

    # find start
    for (i = 1; i <= NF; i++) {
        if ($i == "data:") {
            start = i + 1
            break
        }
    }

    printf("%s:\n", class_name)
    for (i = 2; $i != "data:"; i++) {
        the_function = $i
        printf("\t%s: <%s>\n", $i, @the_function(start, NF) "")
    }
    print ""
}
```

This is the main processing for each record. It prints the class name (with underscores replaced with spaces). It then finds the start of the actual data, saving it in `start`. The last part of the code loops through each function name (from `$2` up to the marker, '`data:`'), calling the function named by the field. The indirect function call itself occurs as a parameter in the call to `printf`. (The `printf` format string uses '`%s`' as the format specifier so that we can use functions that return strings, as well as numbers. Note that the result from the indirect call is concatenated with the empty string, in order to force it to be a string value.)

Here is the result of running the program:

```
$ gawk -f indirectcall.awk class_data1
⊣ Biology 101:
⊣     sum: <352.8>
⊣     average: <88.2>
⊣
⊣ Chemistry 305:
⊣     sum: <356.4>
⊣     average: <89.1>
⊣
⊣ English 401:
⊣     sum: <376.1>
⊣     average: <94.025>
```

The ability to use indirect function calls is more powerful than you may think at first. The C and C++ languages provide “function pointers,” which are a mechanism for calling a function chosen at runtime. One of the most well-known uses of this ability is the C `qsort()` function, which sorts an array using the famous “quick sort” algorithm (see the Wikipedia article (`http://en.wikipedia.org/wiki/Quick_sort`) for more information). To use this function, you supply a pointer to a comparison function. This mechanism allows you to sort arbitrary data in an arbitrary fashion.

We can do something similar using `gawk`, like this:

```
# quicksort.awk --- Quicksort algorithm, with user-supplied
#                   comparison function
# quicksort --- C.A.R. Hoare's quick sort algorithm. See Wikipedia
#               or almost any algorithms or computer science text

function quicksort(data, left, right, less_than,    i, last)
{
    if (left >= right)  # do nothing if array contains fewer
        return          # than two elements

    quicksort_swap(data, left, int((left + right) / 2))
    last = left
    for (i = left + 1; i <= right; i++)
        if (@less_than(data[i], data[left]))
            quicksort_swap(data, ++last, i)
    quicksort_swap(data, left, last)
    quicksort(data, left, last - 1, less_than)
    quicksort(data, last + 1, right, less_than)
}

# quicksort_swap --- helper function for quicksort, should really be inline

function quicksort_swap(data, i, j, temp)
```

```
{
    temp = data[i]
    data[i] = data[j]
    data[j] = temp
}
```

The `quicksort()` function receives the `data` array, the starting and ending indices to sort (`left` and `right`), and the name of a function that performs a "less than" comparison. It then implements the quick sort algorithm.

To make use of the sorting function, we return to our previous example. The first thing to do is write some comparison functions:

```
# num_lt --- do a numeric less than comparison

function num_lt(left, right)
{
    return ((left + 0) < (right + 0))
}

# num_ge --- do a numeric greater than or equal to comparison

function num_ge(left, right)
{
    return ((left + 0) >= (right + 0))
}
```

The `num_ge()` function is needed to perform a descending sort; when used to perform a "less than" test, it actually does the opposite (greater than or equal to), which yields data sorted in descending order.

Next comes a sorting function. It is parameterized with the starting and ending field numbers and the comparison function. It builds an array with the data and calls `quicksort` appropriately, and then formats the results as a single string:

```
# do_sort --- sort the data according to ‘compare’
#             and return it as a string

function do_sort(first, last, compare,      data, i, retval)
{
    delete data
    for (i = 1; first <= last; first++) {
        data[i] = $first
        i++
    }

    quicksort(data, 1, i-1, compare)

    retval = data[1]
    for (i = 2; i in data; i++)
        retval = retval " " data[i]
```

```
    return retval
}
```

Finally, the two sorting functions call `do_sort()`, passing in the names of the two comparison functions:

```
# sort --- sort the data in ascending order and return it as a string

function sort(first, last)
{
    return do_sort(first, last, "num_lt")
}

# rsort --- sort the data in descending order and return it as a string

function rsort(first, last)
{
    return do_sort(first, last, "num_ge")
}
```

Here is an extended version of the data file:

```
Biology_101 sum average sort rsort data: 87.0 92.4 78.5 94.9
Chemistry_305 sum average sort rsort data: 75.2 98.3 94.7 88.2
English_401 sum average sort rsort data: 100.0 95.6 87.1 93.4
```

Finally, here are the results when the enhanced program is run:

```
$ gawk -f quicksort.awk -f indirectcall.awk class_data2
⊣ Biology 101:
⊣     sum: <352.8>
⊣     average: <88.2>
⊣     sort: <78.5 87.0 92.4 94.9>
⊣     rsort: <94.9 92.4 87.0 78.5>
⊣
⊣ Chemistry 305:
⊣     sum: <356.4>
⊣     average: <89.1>
⊣     sort: <75.2 88.2 94.7 98.3>
⊣     rsort: <98.3 94.7 88.2 75.2>
⊣
⊣ English 401:
⊣     sum: <376.1>
⊣     average: <94.025>
⊣     sort: <87.1 93.4 95.6 100.0>
⊣     rsort: <100.0 95.6 93.4 87.1>
```

Remember that you must supply a leading '`@`' in front of an indirect function call.

Unfortunately, indirect function calls cannot be used with the built-in functions. However, you can generally write "wrapper" functions which call the built-in ones, and those can be called indirectly. (Other than, perhaps, the mathematical functions, there is not a lot of reason to try to call the built-in functions indirectly.)

gawk does its best to make indirect function calls efficient. For example, in the following case:

```
for (i = 1; i <= n; i++)
    @the_func()
```

gawk will look up the actual function to call only once.

Part II:
Problem Solving With `awk`

10 A Library of awk Functions

Section 9.2 [User-Defined Functions], page 184, describes how to write your own awk functions. Writing functions is important, because it allows you to encapsulate algorithms and program tasks in a single place. It simplifies programming, making program development more manageable, and making programs more readable.

In their seminal 1976 book, *Software Tools*[1], Brian Kernighan and P.J. Plauger wrote:

> Good Programming is not learned from generalities, but by seeing how significant programs can be made clean, easy to read, easy to maintain and modify, human-engineered, efficient and reliable, by the application of common sense and good programming practices. Careful study and imitation of good programs leads to better writing.

In fact, they felt this idea was so important that they placed this statement on the cover of their book. Because we believe strongly that their statement is correct, this chapter and Chapter 11 [Practical awk Programs], page 231, provide a good-sized body of code for you to read, and we hope, to learn from.

This chapter presents a library of useful awk functions. Many of the sample programs presented later in this book use these functions. The functions are presented here in a progression from simple to complex.

Section 11.3.7 [Extracting Programs from Texinfo Source Files], page 261, presents a program that you can use to extract the source code for these example library functions and programs from the Texinfo source for this book. (This has already been done as part of the gawk distribution.)

If you have written one or more useful, general-purpose awk functions and would like to contribute them to the awk user community, see [How to Contribute], page 9, for more information.

The programs in this chapter and in Chapter 11 [Practical awk Programs], page 231, freely use features that are gawk-specific. Rewriting these programs for different implementations of awk is pretty straightforward.

- Diagnostic error messages are sent to /dev/stderr. Use '| "cat 1>&2"' instead of '> "/dev/stderr"' if your system does not have a /dev/stderr, or if you cannot use gawk.
- A number of programs use nextfile (see Section 7.4.9 [The nextfile Statement], page 133) to skip any remaining input in the input file.
- Finally, some of the programs choose to ignore upper- and lowercase distinctions in their input. They do so by assigning one to IGNORECASE. You can achieve almost the same effect[2] by adding the following rule to the beginning of the program:

  ```
  # ignore case
  { $0 = tolower($0) }
  ```

  Also, verify that all regexp and string constants used in comparisons use only lowercase letters.

---

[1] Sadly, over 35 years later, many of the lessons taught by this book have yet to be learned by a vast number of practicing programmers.

[2] The effects are not identical. Output of the transformed record will be in all lowercase, while IGNORECASE preserves the original contents of the input record.

10.1 Naming Library Function Global Variables

Due to the way the `awk` language evolved, variables are either *global* (usable by the entire program) or *local* (usable just by a specific function). There is no intermediate state analogous to `static` variables in C.

Library functions often need to have global variables that they can use to preserve state information between calls to the function—for example, `getopt()`'s variable `_opti` (see Section 10.4 [Processing Command-Line Options], page 216). Such variables are called *private*, since the only functions that need to use them are the ones in the library.

When writing a library function, you should try to choose names for your private variables that will not conflict with any variables used by either another library function or a user's main program. For example, a name like `i` or `j` is not a good choice, because user programs often use variable names like these for their own purposes.

The example programs shown in this chapter all start the names of their private variables with an underscore ('`_`'). Users generally don't use leading underscores in their variable names, so this convention immediately decreases the chances that the variable name will be accidentally shared with the user's program.

In addition, several of the library functions use a prefix that helps indicate what function or set of functions use the variables—for example, `_pw_byname` in the user database routines (see Section 10.5 [Reading the User Database], page 221). This convention is recommended, since it even further decreases the chance of inadvertent conflict among variable names. Note that this convention is used equally well for variable names and for private function names.[3]

As a final note on variable naming, if a function makes global variables available for use by a main program, it is a good convention to start that variable's name with a capital letter—for example, `getopt()`'s `Opterr` and `Optind` variables (see Section 10.4 [Processing Command-Line Options], page 216). The leading capital letter indicates that it is global, while the fact that the variable name is not all capital letters indicates that the variable is not one of `awk`'s built-in variables, such as `FS`.

It is also important that *all* variables in library functions that do not need to save state are, in fact, declared local.[4] If this is not done, the variable could accidentally be used in the user's program, leading to bugs that are very difficult to track down:

```
function lib_func(x, y,    l1, l2)
{
    ...
    use variable some_var   # some_var should be local
    ...                     # but is not by oversight
}
```

A different convention, common in the Tcl community, is to use a single associative array to hold the values needed by the library function(s), or "package." This significantly decreases the number of actual global names in use. For example, the functions described in Section 10.5 [Reading the User Database], page 221, might have used array elements

[3] While all the library routines could have been rewritten to use this convention, this was not done, in order to show how our own `awk` programming style has evolved and to provide some basis for this discussion.

[4] `gawk`'s `--dump-variables` command-line option is useful for verifying this.

PW_data["inited"], PW_data["total"], PW_data["count"], and PW_data["awklib"], instead of _pw_inited, _pw_awklib, _pw_total, and _pw_count.

The conventions presented in this section are exactly that: conventions. You are not required to write your programs this way—we merely recommend that you do so.

10.2 General Programming

This section presents a number of functions that are of general programming use.

10.2.1 Converting Strings To Numbers

The strtonum() function (see Section 9.1.3 [String-Manipulation Functions], page 161) is a gawk extension. The following function provides an implementation for other versions of awk:

```
# mystrtonum --- convert string to number

function mystrtonum(str,        ret, chars, n, i, k, c)
{
    if (str ~ /^0[0-7]*$/) {
        # octal
        n = length(str)
        ret = 0
        for (i = 1; i <= n; i++) {
            c = substr(str, i, 1)
            if ((k = index("01234567", c)) > 0)
                k-- # adjust for 1-basing in awk

            ret = ret * 8 + k
        }
    } else if (str ~ /^0[xX][[:xdigit:]]+/) {
        # hexadecimal
        str = substr(str, 3)    # lop off leading 0x
        n = length(str)
        ret = 0
        for (i = 1; i <= n; i++) {
            c = substr(str, i, 1)
            c = tolower(c)
            if ((k = index("0123456789", c)) > 0)
                k-- # adjust for 1-basing in awk
            else if ((k = index("abcdef", c)) > 0)
                k += 9

            ret = ret * 16 + k
        }
    } else if (str ~ \
  /^[-+]?([0-9]+([.][0-9]*([Ee][0-9]+)?)?|([.][0-9]+([Ee][-+]?[0-9]+)?))$/) {
        # decimal number, possibly floating point
        ret = str + 0
```

```
    } else
        ret = "NOT-A-NUMBER"

    return ret
}

# BEGIN {     # gawk test harness
#     a[1] = "25"
#     a[2] = ".31"
#     a[3] = "0123"
#     a[4] = "0xdeadBEEF"
#     a[5] = "123.45"
#     a[6] = "1.e3"
#     a[7] = "1.32"
#     a[7] = "1.32E2"
#
#     for (i = 1; i in a; i++)
#         print a[i], strtonum(a[i]), mystrtonum(a[i])
# }
```

The function first looks for C-style octal numbers (base 8). If the input string matches a regular expression describing octal numbers, then `mystrtonum()` loops through each character in the string. It sets `k` to the index in `"01234567"` of the current octal digit. Since the return value is one-based, the '`k--`' adjusts `k` so it can be used in computing the return value.

Similar logic applies to the code that checks for and converts a hexadecimal value, which starts with '`0x`' or '`0X`'. The use of `tolower()` simplifies the computation for finding the correct numeric value for each hexadecimal digit.

Finally, if the string matches the (rather complicated) regexp for a regular decimal integer or floating-point number, the computation '`ret = str + 0`' lets `awk` convert the value to a number.

A commented-out test program is included, so that the function can be tested with `gawk` and the results compared to the built-in `strtonum()` function.

10.2.2 Assertions

When writing large programs, it is often useful to know that a condition or set of conditions is true. Before proceeding with a particular computation, you make a statement about what you believe to be the case. Such a statement is known as an *assertion*. The C language provides an `<assert.h>` header file and corresponding `assert()` macro that the programmer can use to make assertions. If an assertion fails, the `assert()` macro arranges to print a diagnostic message describing the condition that should have been true but was not, and then it kills the program. In C, using `assert()` looks this:

```
#include <assert.h>

int myfunc(int a, double b)
{
     assert(a <= 5 && b >= 17.1);
```

```
        ...
}
```

If the assertion fails, the program prints a message similar to this:

```
prog.c:5: assertion failed: a <= 5 && b >= 17.1
```

The C language makes it possible to turn the condition into a string for use in printing the diagnostic message. This is not possible in `awk`, so this `assert()` function also requires a string version of the condition that is being tested. Following is the function:

```
# assert --- assert that a condition is true. Otherwise exit.

function assert(condition, string)
{
    if (! condition) {
        printf("%s:%d: assertion failed: %s\n",
            FILENAME, FNR, string) > "/dev/stderr"
        _assert_exit = 1
        exit 1
    }
}

END {
    if (_assert_exit)
        exit 1
}
```

The `assert()` function tests the `condition` parameter. If it is false, it prints a message to standard error, using the `string` parameter to describe the failed condition. It then sets the variable `_assert_exit` to one and executes the `exit` statement. The `exit` statement jumps to the `END` rule. If the `END` rules finds `_assert_exit` to be true, it exits immediately.

The purpose of the test in the `END` rule is to keep any other `END` rules from running. When an assertion fails, the program should exit immediately. If no assertions fail, then `_assert_exit` is still false when the `END` rule is run normally, and the rest of the program's `END` rules execute. For all of this to work correctly, `assert.awk` must be the first source file read by `awk`. The function can be used in a program in the following way:

```
function myfunc(a, b)
{
     assert(a <= 5 && b >= 17.1, "a <= 5 && b >= 17.1")
     ...
}
```

If the assertion fails, you see a message similar to the following:

```
mydata:1357: assertion failed: a <= 5 && b >= 17.1
```

There is a small problem with this version of `assert()`. An `END` rule is automatically added to the program calling `assert()`. Normally, if a program consists of just a `BEGIN` rule, the input files and/or standard input are not read. However, now that the program has an `END` rule, `awk` attempts to read the input data files or standard input (see Section 7.1.4.1 [Startup and Cleanup Actions], page 122), most likely causing the program to hang as it waits for input.

There is a simple workaround to this: make sure that such a `BEGIN` rule always ends with an `exit` statement.

10.2.3 Rounding Numbers

The way `printf` and `sprintf()` (see Section 5.5 [Using `printf` Statements for Fancier Printing], page 84) perform rounding often depends upon the system's C `sprintf()` subroutine. On many machines, `sprintf()` rounding is "unbiased," which means it doesn't always round a trailing '`.5`' up, contrary to naive expectations. In unbiased rounding, '`.5`' rounds to even, rather than always up, so 1.5 rounds to 2 but 4.5 rounds to 4. This means that if you are using a format that does rounding (e.g., `"%.0f"`), you should check what your system does. The following function does traditional rounding; it might be useful if your `awk`'s `printf` does unbiased rounding:

```
# round.awk --- do normal rounding

function round(x,   ival, aval, fraction)
{
   ival = int(x)    # integer part, int() truncates

   # see if fractional part
   if (ival == x)   # no fraction
      return ival   # ensure no decimals

   if (x < 0) {
      aval = -x     # absolute value
      ival = int(aval)
      fraction = aval - ival
      if (fraction >= .5)
         return int(x) - 1   # -2.5 --> -3
      else
         return int(x)       # -2.3 --> -2
   } else {
      fraction = x - ival
      if (fraction >= .5)
         return ival + 1
      else
         return ival
   }
}

# test harness
{ print $0, round($0) }
```

10.2.4 The Cliff Random Number Generator

The Cliff random number generator (`http://mathworld.wolfram.com/CliffRandomNumberGenerator.html`) is a very simple random number generator that "passes the noise sphere test for randomness by showing no structure." It is easily programmed, in less than 10 lines of awk code:

```
# cliff_rand.awk --- generate Cliff random numbers

BEGIN { _cliff_seed = 0.1 }

function cliff_rand()
{
    _cliff_seed = (100 * log(_cliff_seed)) % 1
    if (_cliff_seed < 0)
        _cliff_seed = - _cliff_seed
    return _cliff_seed
}
```

This algorithm requires an initial "seed" of 0.1. Each new value uses the current seed as input for the calculation. If the built-in rand() function (see Section 9.1.2 [Numeric Functions], page 159) isn't random enough, you might try using this function instead.

10.2.5 Translating Between Characters and Numbers

One commercial implementation of awk supplies a built-in function, ord(), which takes a character and returns the numeric value for that character in the machine's character set. If the string passed to ord() has more than one character, only the first one is used.

The inverse of this function is chr() (from the function of the same name in Pascal), which takes a number and returns the corresponding character. Both functions are written very nicely in awk; there is no real reason to build them into the awk interpreter:

```
# ord.awk --- do ord and chr

# Global identifiers:
#    _ord_:        numerical values indexed by characters
#    _ord_init:    function to initialize _ord_

BEGIN    { _ord_init() }

function _ord_init(    low, high, i, t)
{
    low = sprintf("%c", 7) # BEL is ascii 7
    if (low == "\a") {    # regular ascii
        low = 0
        high = 127
    } else if (sprintf("%c", 128 + 7) == "\a") {
        # ascii, mark parity
        low = 128
        high = 255
    } else {        # ebcdic(!)
        low = 0
        high = 255
    }
```

```
    for (i = low; i <= high; i++) {
        t = sprintf("%c", i)
        _ord_[t] = i
    }
}
```

Some explanation of the numbers used by `chr` is worthwhile. The most prominent character set in use today is ASCII.[5] Although an 8-bit byte can hold 256 distinct values (from 0 to 255), ASCII only defines characters that use the values from 0 to 127.[6] In the now distant past, at least one minicomputer manufacturer used ASCII, but with mark parity, meaning that the leftmost bit in the byte is always 1. This means that on those systems, characters have numeric values from 128 to 255. Finally, large mainframe systems use the EBCDIC character set, which uses all 256 values. While there are other character sets in use on some older systems, they are not really worth worrying about:

```
function ord(str,    c)
{
    # only first character is of interest
    c = substr(str, 1, 1)
    return _ord_[c]
}

function chr(c)
{
    # force c to be numeric by adding 0
    return sprintf("%c", c + 0)
}

#### test code ####
# BEGIN    \
# {
#    for (;;) {
#        printf("enter a character: ")
#        if (getline var <= 0)
#            break
#        printf("ord(%s) = %d\n", var, ord(var))
#    }
# }
```

An obvious improvement to these functions is to move the code for the `_ord_init` function into the body of the `BEGIN` rule. It was written this way initially for ease of development. There is a "test program" in a `BEGIN` rule, to test the function. It is commented out for production use.

---

[5] This is changing; many systems use Unicode, a very large character set that includes ASCII as a subset. On systems with full Unicode support, a character can occupy up to 32 bits, making simple tests such as used here prohibitively expensive.

[6] ASCII has been extended in many countries to use the values from 128 to 255 for country-specific characters. If your system uses these extensions, you can simplify `_ord_init` to loop from 0 to 255.

10.2.6 Merging an Array into a String

When doing string processing, it is often useful to be able to join all the strings in an array into one long string. The following function, `join()`, accomplishes this task. It is used later in several of the application programs (see Chapter 11 [Practical `awk` Programs], page 231).

Good function design is important; this function needs to be general but it should also have a reasonable default behavior. It is called with an array as well as the beginning and ending indices of the elements in the array to be merged. This assumes that the array indices are numeric—a reasonable assumption since the array was likely created with `split()` (see Section 9.1.3 [String-Manipulation Functions], page 161):

```
# join.awk --- join an array into a string

function join(array, start, end, sep,    result, i)
{
    if (sep == "")
       sep = " "
    else if (sep == SUBSEP) # magic value
       sep = ""
    result = array[start]
    for (i = start + 1; i <= end; i++)
        result = result sep array[i]
    return result
}
```

An optional additional argument is the separator to use when joining the strings back together. If the caller supplies a nonempty value, `join()` uses it; if it is not supplied, it has a null value. In this case, `join()` uses a single space as a default separator for the strings. If the value is equal to `SUBSEP`, then `join()` joins the strings with no separator between them. `SUBSEP` serves as a "magic" value to indicate that there should be no separation between the component strings.[7]

10.2.7 Managing the Time of Day

The `systime()` and `strftime()` functions described in Section 9.1.5 [Time Functions], page 176, provide the minimum functionality necessary for dealing with the time of day in human readable form. While `strftime()` is extensive, the control formats are not necessarily easy to remember or intuitively obvious when reading a program.

The following function, `getlocaltime()`, populates a user-supplied array with preformatted time information. It returns a string with the current time formatted in the same way as the `date` utility:

```
# getlocaltime.awk --- get the time of day in a usable format

# Returns a string in the format of output of date(1)
# Populates the array argument time with individual values:
#    time["second"]       -- seconds (0 - 59)
#    time["minute"]       -- minutes (0 - 59)
```

[7] It would be nice if `awk` had an assignment operator for concatenation. The lack of an explicit operator for concatenation makes string operations more difficult than they really need to be.

```
#    time["hour"]         -- hours (0 - 23)
#    time["althour"]      -- hours (0 - 12)
#    time["monthday"]     -- day of month (1 - 31)
#    time["month"]        -- month of year (1 - 12)
#    time["monthname"]    -- name of the month
#    time["shortmonth"]   -- short name of the month
#    time["year"]         -- year modulo 100 (0 - 99)
#    time["fullyear"]     -- full year
#    time["weekday"]      -- day of week (Sunday = 0)
#    time["altweekday"]   -- day of week (Monday = 0)
#    time["dayname"]      -- name of weekday
#    time["shortdayname"] -- short name of weekday
#    time["yearday"]      -- day of year (0 - 365)
#    time["timezone"]     -- abbreviation of timezone name
#    time["ampm"]         -- AM or PM designation
#    time["weeknum"]      -- week number, Sunday first day
#    time["altweeknum"]   -- week number, Monday first day

function getlocaltime(time,    ret, now, i)
{
    # get time once, avoids unnecessary system calls
    now = systime()

    # return date(1)-style output
    ret = strftime("%a %b %e %H:%M:%S %Z %Y", now)

    # clear out target array
    delete time

    # fill in values, force numeric values to be
    # numeric by adding 0
    time["second"]       = strftime("%S", now) + 0
    time["minute"]       = strftime("%M", now) + 0
    time["hour"]         = strftime("%H", now) + 0
    time["althour"]      = strftime("%I", now) + 0
    time["monthday"]     = strftime("%d", now) + 0
    time["month"]        = strftime("%m", now) + 0
    time["monthname"]    = strftime("%B", now)
    time["shortmonth"]   = strftime("%b", now)
    time["year"]         = strftime("%y", now) + 0
    time["fullyear"]     = strftime("%Y", now) + 0
    time["weekday"]      = strftime("%w", now) + 0
    time["altweekday"]   = strftime("%u", now) + 0
    time["dayname"]      = strftime("%A", now)
    time["shortdayname"] = strftime("%a", now)
    time["yearday"]      = strftime("%j", now) + 0
    time["timezone"]     = strftime("%Z", now)
```

```
    time["ampm"]         = strftime("%p", now)
    time["weeknum"]      = strftime("%U", now) + 0
    time["altweeknum"]   = strftime("%W", now) + 0

    return ret
}
```

The string indices are easier to use and read than the various formats required by `strftime()`. The `alarm` program presented in Section 11.3.2 [An Alarm Clock Program], page 252, uses this function. A more general design for the `getlocaltime()` function would have allowed the user to supply an optional timestamp value to use instead of the current time.

10.2.8 Reading A Whole File At Once

Often, it is convenient to have the entire contents of a file available in memory as a single string. A straightforward but naive way to do that might be as follows:

```
function readfile(file,    tmp, contents)
{
    if ((getline tmp < file) < 0)
        return

    contents = tmp
    while (getline tmp < file) > 0)
        contents = contents RT tmp

    close(file)
    return contents
}
```

This function reads from `file` one record at a time, building up the full contents of the file in the local variable `contents`. It works, but is not necessarily efficient.

The following function, based on a suggestion by Denis Shirokov, reads the entire contents of the named file in one shot:

```
# readfile.awk --- read an entire file at once

function readfile(file,     tmp, save_rs)
{
    save_rs = RS
    RS = "^$"
    getline tmp < file
    close(file)
    RS = save_rs

    return tmp
}
```

It works by setting `RS` to '`^$`', a regular expression that will never match if the file has contents. `gawk` reads data from the file into `tmp` attempting to match `RS`. The match fails after each read, but fails quickly, such that `gawk` fills `tmp` with the entire contents of the file. (See Section 4.1 [How Input Is Split into Records], page 55, for information on `RT` and `RS`.)

In the case that `file` is empty, the return value is the null string. Thus calling code may use something like:

```
contents = readfile("/some/path")
if (length(contents) == 0)
    # file was empty ...
```

This tests the result to see if it is empty or not. An equivalent test would be '`contents == ""`'.

10.3 Data File Management

This section presents functions that are useful for managing command-line data files.

10.3.1 Noting Data File Boundaries

The `BEGIN` and `END` rules are each executed exactly once at the beginning and end of your `awk` program, respectively (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122). We (the `gawk` authors) once had a user who mistakenly thought that the `BEGIN` rule is executed at the beginning of each data file and the `END` rule is executed at the end of each data file.

When informed that this was not the case, the user requested that we add new special patterns to `gawk`, named `BEGIN_FILE` and `END_FILE`, that would have the desired behavior. He even supplied us the code to do so.

Adding these special patterns to `gawk` wasn't necessary; the job can be done cleanly in `awk` itself, as illustrated by the following library program. It arranges to call two user-supplied functions, `beginfile()` and `endfile()`, at the beginning and end of each data file. Besides solving the problem in only nine(!) lines of code, it does so *portably*; this works with any implementation of `awk`:

```
# transfile.awk
#
# Give the user a hook for filename transitions
#
# The user must supply functions beginfile() and endfile()
# that each take the name of the file being started or
# finished, respectively.

FILENAME != _oldfilename \
{
    if (_oldfilename != "")
        endfile(_oldfilename)
    _oldfilename = FILENAME
    beginfile(FILENAME)
}

END   { endfile(FILENAME) }
```

This file must be loaded before the user's "main" program, so that the rule it supplies is executed first.

This rule relies on awk's FILENAME variable that automatically changes for each new data file. The current file name is saved in a private variable, _oldfilename. If FILENAME does not equal _oldfilename, then a new data file is being processed and it is necessary to call endfile() for the old file. Because endfile() should only be called if a file has been processed, the program first checks to make sure that _oldfilename is not the null string. The program then assigns the current file name to _oldfilename and calls beginfile() for the file. Because, like all awk variables, _oldfilename is initialized to the null string, this rule executes correctly even for the first data file.

The program also supplies an END rule to do the final processing for the last file. Because this END rule comes before any END rules supplied in the "main" program, endfile() is called first. Once again the value of multiple BEGIN and END rules should be clear.

If the same data file occurs twice in a row on the command line, then endfile() and beginfile() are not executed at the end of the first pass and at the beginning of the second pass. The following version solves the problem:

```
# ftrans.awk --- handle data file transitions
#
# user supplies beginfile() and endfile() functions

FNR == 1 {
    if (_filename_ != "")
        endfile(_filename_)
    _filename_ = FILENAME
    beginfile(FILENAME)
}

END  { endfile(_filename_) }
```

Section 11.2.7 [Counting Things], page 249, shows how this library function can be used and how it simplifies writing the main program.

So Why Does gawk have BEGINFILE and ENDFILE?

You are probably wondering, if beginfile() and endfile() functions can do the job, why does gawk have BEGINFILE and ENDFILE patterns (see Section 7.1.5 [The BEGINFILE and ENDFILE Special Patterns], page 123)?

Good question. Normally, if awk cannot open a file, this causes an immediate fatal error. In this case, there is no way for a user-defined function to deal with the problem, since the mechanism for calling it relies on the file being open and at the first record. Thus, the main reason for BEGINFILE is to give you a "hook" to catch files that cannot be processed. ENDFILE exists for symmetry, and because it provides an easy way to do per-file cleanup processing.

10.3.2 Rereading the Current File

Another request for a new built-in function was for a `rewind()` function that would make it possible to reread the current file. The requesting user didn't want to have to use `getline` (see Section 4.9 [Explicit Input with `getline`], page 73) inside a loop.

However, as long as you are not in the `END` rule, it is quite easy to arrange to immediately close the current input file and then start over with it from the top. For lack of a better name, we'll call it `rewind()`:

```
# rewind.awk --- rewind the current file and start over

function rewind(    i)
{
    # shift remaining arguments up
    for (i = ARGC; i > ARGIND; i--)
        ARGV[i] = ARGV[i-1]

    # make sure gawk knows to keep going
    ARGC++

    # make current file next to get done
    ARGV[ARGIND+1] = FILENAME

    # do it
    nextfile
}
```

This code relies on the `ARGIND` variable (see Section 7.5.2 [Built-in Variables That Convey Information], page 137), which is specific to `gawk`. If you are not using `gawk`, you can use ideas presented in the previous section to either update `ARGIND` on your own or modify this code as appropriate.

The `rewind()` function also relies on the `nextfile` keyword (see Section 7.4.9 [The `nextfile` Statement], page 133).

10.3.3 Checking for Readable Data Files

Normally, if you give `awk` a data file that isn't readable, it stops with a fatal error. There are times when you might want to just ignore such files and keep going. You can do this by prepending the following program to your `awk` program:

```
# readable.awk --- library file to skip over unreadable files

BEGIN {
    for (i = 1; i < ARGC; i++) {
        if (ARGV[i] ~ /^[[:alpha:]_][[:alnum:]_]*=.*/ \
            || ARGV[i] == "-" || ARGV[i] == "/dev/stdin")
            continue    # assignment or standard input
        else if ((getline junk < ARGV[i]) < 0) # unreadable
            delete ARGV[i]
        else
```

```
                close(ARGV[i])
        }
    }
```

This works, because the `getline` won't be fatal. Removing the element from `ARGV` with `delete` skips the file (since it's no longer in the list). See also Section 7.5.3 [Using ARGC and ARGV], page 143.

10.3.4 Checking For Zero-length Files

All known `awk` implementations silently skip over zero-length files. This is a by-product of `awk`'s implicit read-a-record-and-match-against-the-rules loop: when `awk` tries to read a record from an empty file, it immediately receives an end of file indication, closes the file, and proceeds on to the next command-line data file, *without* executing any user-level `awk` program code.

Using `gawk`'s `ARGIND` variable (see Section 7.5 [Built-in Variables], page 134), it is possible to detect when an empty data file has been skipped. Similar to the library file presented in Section 10.3.1 [Noting Data File Boundaries], page 212, the following library file calls a function named `zerofile()` that the user must provide. The arguments passed are the file name and the position in `ARGV` where it was found:

```
    # zerofile.awk --- library file to process empty input files

    BEGIN { Argind = 0 }

    ARGIND > Argind + 1 {
        for (Argind++; Argind < ARGIND; Argind++)
            zerofile(ARGV[Argind], Argind)
    }

    ARGIND != Argind { Argind = ARGIND }

    END {
        if (ARGIND > Argind)
            for (Argind++; Argind <= ARGIND; Argind++)
                zerofile(ARGV[Argind], Argind)
    }
```

The user-level variable `Argind` allows the `awk` program to track its progress through `ARGV`. Whenever the program detects that `ARGIND` is greater than '`Argind + 1`', it means that one or more empty files were skipped. The action then calls `zerofile()` for each such file, incrementing `Argind` along the way.

The '`Argind != ARGIND`' rule simply keeps `Argind` up to date in the normal case.

Finally, the `END` rule catches the case of any empty files at the end of the command-line arguments. Note that the test in the condition of the `for` loop uses the '`<=`' operator, not '`<`'.

As an exercise, you might consider whether this same problem can be solved without relying on `gawk`'s `ARGIND` variable.

As a second exercise, revise this code to handle the case where an intervening value in ARGV is a variable assignment.

10.3.5 Treating Assignments as File Names

Occasionally, you might not want awk to process command-line variable assignments (see Section 6.1.3.2 [Assigning Variables on the Command Line], page 100). In particular, if you have a file name that contain an '=' character, awk treats the file name as an assignment, and does not process it.

Some users have suggested an additional command-line option for gawk to disable command-line assignments. However, some simple programming with a library file does the trick:

```
# noassign.awk --- library file to avoid the need for a
# special option that disables command-line assignments

function disable_assigns(argc, argv,    i)
{
    for (i = 1; i < argc; i++)
        if (argv[i] ~ /^[[:alpha:]_][[:alnum:]_]*=.*/)
            argv[i] = ("./" argv[i])
}

BEGIN {
    if (No_command_assign)
        disable_assigns(ARGC, ARGV)
}
```

You then run your program this way:

```
awk -v No_command_assign=1 -f noassign.awk -f yourprog.awk *
```

The function works by looping through the arguments. It prepends './' to any argument that matches the form of a variable assignment, turning that argument into a file name.

The use of No_command_assign allows you to disable command-line assignments at invocation time, by giving the variable a true value. When not set, it is initially zero (i.e., false), so the command-line arguments are left alone.

10.4 Processing Command-Line Options

Most utilities on POSIX compatible systems take options on the command line that can be used to change the way a program behaves. awk is an example of such a program (see Section 2.2 [Command-Line Options], page 29). Often, options take *arguments*; i.e., data that the program needs to correctly obey the command-line option. For example, awk's -F option requires a string to use as the field separator. The first occurrence on the command line of either -- or a string that does not begin with '-' ends the options.

Modern Unix systems provide a C function named getopt() for processing command-line arguments. The programmer provides a string describing the one-letter options. If an option requires an argument, it is followed in the string with a colon. getopt() is also passed the count and values of the command-line arguments and is called in a loop. getopt() processes the command-line arguments for option letters. Each time around the loop, it returns a single character representing the next option letter that it finds, or '?' if it finds an invalid option. When it returns −1, there are no options left on the command line.

When using `getopt()`, options that do not take arguments can be grouped together. Furthermore, options that take arguments require that the argument be present. The argument can immediately follow the option letter, or it can be a separate command-line argument.

Given a hypothetical program that takes three command-line options, `-a`, `-b`, and `-c`, where `-b` requires an argument, all of the following are valid ways of invoking the program:

```
prog -a -b foo -c data1 data2 data3
prog -ac -bfoo -- data1 data2 data3
prog -acbfoo data1 data2 data3
```

Notice that when the argument is grouped with its option, the rest of the argument is considered to be the option's argument. In this example, `-acbfoo` indicates that all of the `-a`, `-b`, and `-c` options were supplied, and that '`foo`' is the argument to the `-b` option.

`getopt()` provides four external variables that the programmer can use:

`optind` The index in the argument value array (`argv`) where the first nonoption command-line argument can be found.

`optarg` The string value of the argument to an option.

`opterr` Usually `getopt()` prints an error message when it finds an invalid option. Setting `opterr` to zero disables this feature. (An application might want to print its own error message.)

`optopt` The letter representing the command-line option.

The following C fragment shows how `getopt()` might process command-line arguments for `awk`:

```
int
main(int argc, char *argv[])
{
    ...
    /* print our own message */
    opterr = 0;
    while ((c = getopt(argc, argv, "v:f:F:W:")) != -1) {
        switch (c) {
        case 'f':    /* file */
            ...
            break;
        case 'F':    /* field separator */
            ...
            break;
        case 'v':    /* variable assignment */
            ...
            break;
        case 'W':    /* extension */
```

```
                ...
                break;
            case '?':
            default:
                usage();
                break;
            }
        }
        ...
    }
```

As a side point, gawk actually uses the GNU getopt_long() function to process both normal and GNU-style long options (see Section 2.2 [Command-Line Options], page 29).

The abstraction provided by getopt() is very useful and is quite handy in awk programs as well. Following is an awk version of getopt(). This function highlights one of the greatest weaknesses in awk, which is that it is very poor at manipulating single characters. Repeated calls to substr() are necessary for accessing individual characters (see Section 9.1.3 [String-Manipulation Functions], page 161).[8]

The discussion that follows walks through the code a bit at a time:

```
# getopt.awk --- Do C library getopt(3) function in awk

# External variables:
#    Optind -- index in ARGV of first nonoption argument
#    Optarg -- string value of argument to current option
#    Opterr -- if nonzero, print our own diagnostic
#    Optopt -- current option letter

# Returns:
#    -1     at end of options
#    "?"    for unrecognized option
#    <c>    a character representing the current option

# Private Data:
#    _opti  -- index in multiflag option, e.g., -abc
```

The function starts out with comments presenting a list of the global variables it uses, what the return values are, what they mean, and any global variables that are "private" to this library function. Such documentation is essential for any program, and particularly for library functions.

The getopt() function first checks that it was indeed called with a string of options (the options parameter). If options has a zero length, getopt() immediately returns −1:

```
function getopt(argc, argv, options,    thisopt, i)
{
    if (length(options) == 0)    # no options given
        return -1
```

[8] This function was written before gawk acquired the ability to split strings into single characters using "" as the separator. We have left it alone, since using substr() is more portable.

```
    if (argv[Optind] == "--") {  # all done
        Optind++
        _opti = 0
        return -1
    } else if (argv[Optind] !~ /^-[^:[:space:]]/) {
        _opti = 0
        return -1
    }
```

The next thing to check for is the end of the options. A `--` ends the command-line options, as does any command-line argument that does not begin with a '`-`'. `Optind` is used to step through the array of command-line arguments; it retains its value across calls to `getopt()`, because it is a global variable.

The regular expression that is used, `/^-[^:[:space:]/`, checks for a '`-`' followed by anything that is not whitespace and not a colon. If the current command-line argument does not match this pattern, it is not an option, and it ends option processing. Continuing on:

```
    if (_opti == 0)
        _opti = 2
    thisopt = substr(argv[Optind], _opti, 1)
    Optopt = thisopt
    i = index(options, thisopt)
    if (i == 0) {
        if (Opterr)
            printf("%c -- invalid option\n",
                                  thisopt) > "/dev/stderr"
        if (_opti >= length(argv[Optind])) {
            Optind++
            _opti = 0
        } else
            _opti++
        return "?"
    }
```

The `_opti` variable tracks the position in the current command-line argument (`argv[Optind]`). If multiple options are grouped together with one '`-`' (e.g., `-abx`), it is necessary to return them to the user one at a time.

If `_opti` is equal to zero, it is set to two, which is the index in the string of the next character to look at (we skip the '`-`', which is at position one). The variable `thisopt` holds the character, obtained with `substr()`. It is saved in `Optopt` for the main program to use.

If `thisopt` is not in the `options` string, then it is an invalid option. If `Opterr` is nonzero, `getopt()` prints an error message on the standard error that is similar to the message from the C version of `getopt()`.

Because the option is invalid, it is necessary to skip it and move on to the next option character. If `_opti` is greater than or equal to the length of the current command-line argument, it is necessary to move on to the next argument, so `Optind` is incremented and `_opti` is reset to zero. Otherwise, `Optind` is left alone and `_opti` is merely incremented.

In any case, because the option is invalid, `getopt()` returns `"?"`. The main program can examine `Optopt` if it needs to know what the invalid option letter actually is. Continuing on:

```
        if (substr(options, i + 1, 1) == ":") {
            # get option argument
            if (length(substr(argv[Optind], _opti + 1)) > 0)
                Optarg = substr(argv[Optind], _opti + 1)
            else
                Optarg = argv[++Optind]
            _opti = 0
        } else
            Optarg = ""
```

If the option requires an argument, the option letter is followed by a colon in the `options` string. If there are remaining characters in the current command-line argument (`argv[Optind]`), then the rest of that string is assigned to `Optarg`. Otherwise, the next command-line argument is used ('`-xFOO`' versus '`-x FOO`'). In either case, `_opti` is reset to zero, because there are no more characters left to examine in the current command-line argument. Continuing:

```
        if (_opti == 0 || _opti >= length(argv[Optind])) {
            Optind++
            _opti = 0
        } else
            _opti++
        return thisopt
    }
```

Finally, if `_opti` is either zero or greater than the length of the current command-line argument, it means this element in `argv` is through being processed, so `Optind` is incremented to point to the next element in `argv`. If neither condition is true, then only `_opti` is incremented, so that the next option letter can be processed on the next call to `getopt()`.

The `BEGIN` rule initializes both `Opterr` and `Optind` to one. `Opterr` is set to one, since the default behavior is for `getopt()` to print a diagnostic message upon seeing an invalid option. `Optind` is set to one, since there's no reason to look at the program name, which is in `ARGV[0]`:

```
    BEGIN {
        Opterr = 1    # default is to diagnose
        Optind = 1    # skip ARGV[0]

        # test program
        if (_getopt_test) {
            while ((_go_c = getopt(ARGC, ARGV, "ab:cd")) != -1)
                printf("c = <%c>, optarg = <%s>\n",
                                           _go_c, Optarg)
```

```
            printf("non-option arguments:\n")
            for (; Optind < ARGC; Optind++)
                printf("\tARGV[%d] = <%s>\n",
                                        Optind, ARGV[Optind])
        }
    }
```

The rest of the BEGIN rule is a simple test program. Here is the result of two sample runs of the test program:

```
$ awk -f getopt.awk -v _getopt_test=1 -- -a -cbARG bax -x
⊣ c = <a>, optarg = <>
⊣ c = <c>, optarg = <>
⊣ c = <b>, optarg = <ARG>
⊣ non-option arguments:
⊣         ARGV[3] = <bax>
⊣         ARGV[4] = <-x>

$ awk -f getopt.awk -v _getopt_test=1 -- -a -x -- xyz abc
⊣ c = <a>, optarg = <>
error  x -- invalid option
⊣ c = <?>, optarg = <>
⊣ non-option arguments:
⊣         ARGV[4] = <xyz>
⊣         ARGV[5] = <abc>
```

In both runs, the first -- terminates the arguments to awk, so that it does not try to interpret the -a, etc., as its own options.

> **NOTE:** After getopt() is through, it is the responsibility of the user level code to clear out all the elements of ARGV from 1 to Optind, so that awk does not try to process the command-line options as file names.

Several of the sample programs presented in Chapter 11 [Practical awk Programs], page 231, use getopt() to process their arguments.

10.5 Reading the User Database

The PROCINFO array (see Section 7.5 [Built-in Variables], page 134) provides access to the current user's real and effective user and group ID numbers, and if available, the user's supplementary group set. However, because these are numbers, they do not provide very useful information to the average user. There needs to be some way to find the user information associated with the user and group ID numbers. This section presents a suite of functions for retrieving information from the user database. See Section 10.6 [Reading the Group Database], page 225, for a similar suite that retrieves information from the group database.

The POSIX standard does not define the file where user information is kept. Instead, it provides the <pwd.h> header file and several C language subroutines for obtaining user information. The primary function is getpwent(), for "get password entry." The "password" comes from the original user database file, /etc/passwd, which stores user information, along with the encrypted passwords (hence the name).

While an `awk` program could simply read `/etc/passwd` directly, this file may not contain complete information about the system's set of users.[9] To be sure you are able to produce a readable and complete version of the user database, it is necessary to write a small C program that calls `getpwent()`. `getpwent()` is defined as returning a pointer to a `struct passwd`. Each time it is called, it returns the next entry in the database. When there are no more entries, it returns `NULL`, the null pointer. When this happens, the C program should call `endpwent()` to close the database. Following is `pwcat`, a C program that "cats" the password database:

```
/*
 * pwcat.c
 *
 * Generate a printable version of the password database
 */
#include <stdio.h>
#include <pwd.h>

int
main(int argc, char **argv)
{
    struct passwd *p;

    while ((p = getpwent()) != NULL)
        printf("%s:%s:%ld:%ld:%s:%s:%s\n",
            p->pw_name, p->pw_passwd, (long) p->pw_uid,
            (long) p->pw_gid, p->pw_gecos, p->pw_dir, p->pw_shell);

    endpwent();
    return 0;
}
```

If you don't understand C, don't worry about it. The output from `pwcat` is the user database, in the traditional `/etc/passwd` format of colon-separated fields. The fields are:

Login name
: The user's login name.

Encrypted password
: The user's encrypted password. This may not be available on some systems.

User-ID
: The user's numeric user ID number. (On some systems it's a C `long`, and not an `int`. Thus we cast it to `long` for all cases.)

Group-ID
: The user's numeric group ID number. (Similar comments about `long` vs. `int` apply here.)

Full name
: The user's full name, and perhaps other information associated with the user.

Home directory
: The user's login (or "home") directory (familiar to shell programmers as `$HOME`).

[9] It is often the case that password information is stored in a network database.

Login shell
: The program that is run when the user logs in. This is usually a shell, such as Bash.

A few lines representative of pwcat's output are as follows:

```
$ pwcat
-| root:3Ov02d5VaUPB6:0:1:Operator:/:/bin/sh
-| nobody:*:65534:65534::/:
-| daemon:*:1:1::/:
-| sys:*:2:2::/:/bin/csh
-| bin:*:3:3::/bin:
-| arnold:xyzzy:2076:10:Arnold Robbins:/home/arnold:/bin/sh
-| miriam:yxaay:112:10:Miriam Robbins:/home/miriam:/bin/sh
-| andy:abcca2:113:10:Andy Jacobs:/home/andy:/bin/sh
...
```

With that introduction, following is a group of functions for getting user information. There are several functions here, corresponding to the C functions of the same names:

```
# passwd.awk --- access password file information

BEGIN {
    # tailor this to suit your system
    _pw_awklib = "/usr/local/libexec/awk/"
}

function _pw_init(    oldfs, oldrs, olddol0, pwcat, using_fw, using_fpat)
{
    if (_pw_inited)
        return

    oldfs = FS
    oldrs = RS
    olddol0 = $0
    using_fw = (PROCINFO["FS"] == "FIELDWIDTHS")
    using_fpat = (PROCINFO["FS"] == "FPAT")
    FS = ":"
    RS = "\n"

    pwcat = _pw_awklib "pwcat"
    while ((pwcat | getline) > 0) {
        _pw_byname[$1] = $0
        _pw_byuid[$3] = $0
        _pw_bycount[++_pw_total] = $0
    }
    close(pwcat)
    _pw_count = 0
    _pw_inited = 1
    FS = oldfs
```

```
        if (using_fw)
            FIELDWIDTHS = FIELDWIDTHS
        else if (using_fpat)
            FPAT = FPAT
        RS = oldrs
        $0 = olddol0
    }
```

The BEGIN rule sets a private variable to the directory where pwcat is stored. Because it is used to help out an awk library routine, we have chosen to put it in /usr/local/libexec/awk; however, you might want it to be in a different directory on your system.

The function _pw_init() keeps three copies of the user information in three associative arrays. The arrays are indexed by username (_pw_byname), by user ID number (_pw_byuid), and by order of occurrence (_pw_bycount). The variable _pw_inited is used for efficiency, since _pw_init() needs to be called only once.

Because this function uses getline to read information from pwcat, it first saves the values of FS, RS, and $0. It notes in the variable using_fw whether field splitting with FIELDWIDTHS is in effect or not. Doing so is necessary, since these functions could be called from anywhere within a user's program, and the user may have his or her own way of splitting records and fields.

The using_fw variable checks PROCINFO["FS"], which is "FIELDWIDTHS" if field splitting is being done with FIELDWIDTHS. This makes it possible to restore the correct field-splitting mechanism later. The test can only be true for gawk. It is false if using FS or FPAT, or on some other awk implementation.

The code that checks for using FPAT, using using_fpat and PROCINFO["FS"] is similar.

The main part of the function uses a loop to read database lines, split the line into fields, and then store the line into each array as necessary. When the loop is done, _pw_init() cleans up by closing the pipeline, setting _pw_inited to one, and restoring FS (and FIELDWIDTHS or FPAT if necessary), RS, and $0. The use of _pw_count is explained shortly.

The getpwnam() function takes a username as a string argument. If that user is in the database, it returns the appropriate line. Otherwise, it relies on the array reference to a nonexistent element to create the element with the null string as its value:

```
    function getpwnam(name)
    {
        _pw_init()
        return _pw_byname[name]
    }
```

Similarly, the getpwuid function takes a user ID number argument. If that user number is in the database, it returns the appropriate line. Otherwise, it returns the null string:

```
    function getpwuid(uid)
    {
        _pw_init()
        return _pw_byuid[uid]
    }
```

The `getpwent()` function simply steps through the database, one entry at a time. It uses `_pw_count` to track its current position in the `_pw_bycount` array:

```
function getpwent()
{
    _pw_init()
    if (_pw_count < _pw_total)
        return _pw_bycount[++_pw_count]
    return ""
}
```

The `endpwent()` function resets `_pw_count` to zero, so that subsequent calls to `getpwent()` start over again:

```
function endpwent()
{
    _pw_count = 0
}
```

A conscious design decision in this suite is that each subroutine calls `_pw_init()` to initialize the database arrays. The overhead of running a separate process to generate the user database, and the I/O to scan it, are only incurred if the user's main program actually calls one of these functions. If this library file is loaded along with a user's program, but none of the routines are ever called, then there is no extra runtime overhead. (The alternative is move the body of `_pw_init()` into a `BEGIN` rule, which always runs `pwcat`. This simplifies the code but runs an extra process that may never be needed.)

In turn, calling `_pw_init()` is not too expensive, because the `_pw_inited` variable keeps the program from reading the data more than once. If you are worried about squeezing every last cycle out of your `awk` program, the check of `_pw_inited` could be moved out of `_pw_init()` and duplicated in all the other functions. In practice, this is not necessary, since most `awk` programs are I/O-bound, and such a change would clutter up the code.

The `id` program in Section 11.2.3 [Printing out User Information], page 240, uses these functions.

10.6 Reading the Group Database

Much of the discussion presented in Section 10.5 [Reading the User Database], page 221, applies to the group database as well. Although there has traditionally been a well-known file (`/etc/group`) in a well-known format, the POSIX standard only provides a set of C library routines (`<grp.h>` and `getgrent()`) for accessing the information. Even though this file may exist, it may not have complete information. Therefore, as with the user database, it is necessary to have a small C program that generates the group database as its output. `grcat`, a C program that "cats" the group database, is as follows:

```
/*
 * grcat.c
 *
 * Generate a printable version of the group database
 */
#include <stdio.h>
#include <grp.h>
```

```
int
main(int argc, char **argv)
{
    struct group *g;
    int i;

    while ((g = getgrent()) != NULL) {
        printf("%s:%s:%ld:", g->gr_name, g->gr_passwd,
                                     (long) g->gr_gid);
        for (i = 0; g->gr_mem[i] != NULL; i++) {
            printf("%s", g->gr_mem[i]);
            if (g->gr_mem[i+1] != NULL)
                putchar(',');
        }
        putchar('\n');
    }
    endgrent();
    return 0;
}
```

Each line in the group database represents one group. The fields are separated with colons and represent the following information:

Group Name
: The group's name.

Group Password
: The group's encrypted password. In practice, this field is never used; it is usually empty or set to '*'.

Group ID Number
: The group's numeric group ID number; this number must be unique within the file. (On some systems it's a C `long`, and not an `int`. Thus we cast it to `long` for all cases.)

Group Member List
: A comma-separated list of user names. These users are members of the group. Modern Unix systems allow users to be members of several groups simultaneously. If your system does, then there are elements `"group1"` through `"groupN"` in `PROCINFO` for those group ID numbers. (Note that `PROCINFO` is a `gawk` extension; see Section 7.5 [Built-in Variables], page 134.)

Here is what running `grcat` might produce:

```
$ grcat
⊣ wheel:*:0:arnold
⊣ nogroup:*:65534:
⊣ daemon:*:1:
⊣ kmem:*:2:
⊣ staff:*:10:arnold,miriam,andy
```

```
⊣ other:*:20:
...
```

Here are the functions for obtaining information from the group database. There are several, modeled after the C library functions of the same names:

```
# group.awk --- functions for dealing with the group file

BEGIN    \
{
    # Change to suit your system
    _gr_awklib = "/usr/local/libexec/awk/"
}

function _gr_init(    oldfs, oldrs, olddol0, grcat,
                             using_fw, using_fpat, n, a, i)
{
    if (_gr_inited)
        return

    oldfs = FS
    oldrs = RS
    olddol0 = $0
    using_fw = (PROCINFO["FS"] == "FIELDWIDTHS")
    using_fpat = (PROCINFO["FS"] == "FPAT")
    FS = ":"
    RS = "\n"

    grcat = _gr_awklib "grcat"
    while ((grcat | getline) > 0) {
        if ($1 in _gr_byname)
            _gr_byname[$1] = _gr_byname[$1] "," $4
        else
            _gr_byname[$1] = $0
        if ($3 in _gr_bygid)
            _gr_bygid[$3] = _gr_bygid[$3] "," $4
        else
            _gr_bygid[$3] = $0

        n = split($4, a, "[ \t]*,[ \t]*")
        for (i = 1; i <= n; i++)
            if (a[i] in _gr_groupsbyuser)
                _gr_groupsbyuser[a[i]] = \
                    _gr_groupsbyuser[a[i]] " " $1
            else
                _gr_groupsbyuser[a[i]] = $1

        _gr_bycount[++_gr_count] = $0
```

```
        }
        close(grcat)
        _gr_count = 0
        _gr_inited++
        FS = oldfs
        if (using_fw)
            FIELDWIDTHS = FIELDWIDTHS
        else if (using_fpat)
            FPAT = FPAT
        RS = oldrs
        $0 = olddol0
    }
```

The BEGIN rule sets a private variable to the directory where grcat is stored. Because it is used to help out an awk library routine, we have chosen to put it in /usr/local/libexec/awk. You might want it to be in a different directory on your system.

These routines follow the same general outline as the user database routines (see Section 10.5 [Reading the User Database], page 221). The _gr_inited variable is used to ensure that the database is scanned no more than once. The _gr_init() function first saves FS, RS, and $0, and then sets FS and RS to the correct values for scanning the group information. It also takes care to note whether FIELDWIDTHS or FPAT is being used, and to restore the appropriate field splitting mechanism.

The group information is stored is several associative arrays. The arrays are indexed by group name (_gr_byname), by group ID number (_gr_bygid), and by position in the database (_gr_bycount). There is an additional array indexed by user name (_gr_groupsbyuser), which is a space-separated list of groups to which each user belongs.

Unlike the user database, it is possible to have multiple records in the database for the same group. This is common when a group has a large number of members. A pair of such entries might look like the following:

```
tvpeople:*:101:johnny,jay,arsenio
tvpeople:*:101:david,conan,tom,joan
```

For this reason, _gr_init() looks to see if a group name or group ID number is already seen. If it is, then the user names are simply concatenated onto the previous list of users. (There is actually a subtle problem with the code just presented. Suppose that the first time there were no names. This code adds the names with a leading comma. It also doesn't check that there is a $4.)

Finally, _gr_init() closes the pipeline to grcat, restores FS (and FIELDWIDTHS or FPAT if necessary), RS, and $0, initializes _gr_count to zero (it is used later), and makes _gr_inited nonzero.

The getgrnam() function takes a group name as its argument, and if that group exists, it is returned. Otherwise, it relies on the array reference to a nonexistent element to create the element with the null string as its value:

```
function getgrnam(group)
{
    _gr_init()
```

```
    return _gr_byname[group]
}
```

The getgrgid() function is similar; it takes a numeric group ID and looks up the information associated with that group ID:

```
function getgrgid(gid)
{
    _gr_init()
    return _gr_bygid[gid]
}
```

The getgruser() function does not have a C counterpart. It takes a user name and returns the list of groups that have the user as a member:

```
function getgruser(user)
{
    _gr_init()
    return _gr_groupsbyuser[user]
}
```

The getgrent() function steps through the database one entry at a time. It uses _gr_count to track its position in the list:

```
function getgrent()
{
    _gr_init()
    if (++_gr_count in _gr_bycount)
        return _gr_bycount[_gr_count]
    return ""
}
```

The endgrent() function resets _gr_count to zero so that getgrent() can start over again:

```
function endgrent()
{
    _gr_count = 0
}
```

As with the user database routines, each function calls _gr_init() to initialize the arrays. Doing so only incurs the extra overhead of running grcat if these functions are used (as opposed to moving the body of _gr_init() into a BEGIN rule).

Most of the work is in scanning the database and building the various associative arrays. The functions that the user calls are themselves very simple, relying on awk's associative arrays to do work.

The id program in Section 11.2.3 [Printing out User Information], page 240, uses these functions.

10.7 Traversing Arrays of Arrays

Section 8.6 [Arrays of Arrays], page 156, described how gawk provides arrays of arrays. In particular, any element of an array may be either a scalar, or another array. The isarray() function (see Section 9.1.7 [Getting Type Information], page 183) lets you distinguish an array from a scalar. The following function, `walk_array()`, recursively traverses an array, printing each element's indices and value. You call it with the array and a string representing the name of the array:

```
function walk_array(arr, name,      i)
{
    for (i in arr) {
        if (isarray(arr[i]))
            walk_array(arr[i], (name "[" i "]"))
        else
            printf("%s[%s] = %s\n", name, i, arr[i])
    }
}
```

It works by looping over each element of the array. If any given element is itself an array, the function calls itself recursively, passing the subarray and a new string representing the current index. Otherwise, the function simply prints the element's name, index, and value. Here is a main program to demonstrate:

```
BEGIN {
    a[1] = 1
    a[2][1] = 21
    a[2][2] = 22
    a[3] = 3
    a[4][1][1] = 411
    a[4][2] = 42

    walk_array(a, "a")
}
```

When run, the program produces the following output:

```
$ gawk -f walk_array.awk
⊣ a[4][1][1] = 411
⊣ a[4][2] = 42
⊣ a[1] = 1
⊣ a[2][1] = 21
⊣ a[2][2] = 22
⊣ a[3] = 3
```

Walking an array and processing each element is a general-purpose operation. You might want to consider generalizing the `walk_array()` function by adding an additional parameter named `process`.

Then, inside the loop, instead of simply printing the array element's index and value, use the indirect function call syntax (see Section 9.3 [Indirect Function Calls], page 193) on `process`, passing it the index and the value.

When calling `walk_array()`, you would pass the name of a user-defined function that expects to receive and index and a value, and then processes the element.

11 Practical awk Programs

Chapter 10 [A Library of awk Functions], page 201, presents the idea that reading programs in a language contributes to learning that language. This chapter continues that theme, presenting a potpourri of awk programs for your reading enjoyment. There are three sections. The first describes how to run the programs presented in this chapter.

The second presents awk versions of several common POSIX utilities. These are programs that you are hopefully already familiar with, and therefore, whose problems are understood. By reimplementing these programs in awk, you can focus on the awk-related aspects of solving the programming problem.

The third is a grab bag of interesting programs. These solve a number of different data-manipulation and management problems. Many of the programs are short, which emphasizes awk's ability to do a lot in just a few lines of code.

Many of these programs use library functions presented in Chapter 10 [A Library of awk Functions], page 201.

11.1 Running the Example Programs

To run a given program, you would typically do something like this:

```
awk -f program -- options files
```

Here, *program* is the name of the awk program (such as cut.awk), *options* are any command-line options for the program that start with a '-', and *files* are the actual data files.

If your system supports the '#!' executable interpreter mechanism (see Section 1.1.4 [Executable awk Programs], page 17), you can instead run your program directly:

```
cut.awk -c1-8 myfiles > results
```

If your awk is not gawk, you may instead need to use this:

```
cut.awk -- -c1-8 myfiles > results
```

11.2 Reinventing Wheels for Fun and Profit

This section presents a number of POSIX utilities implemented in awk. Reinventing these programs in awk is often enjoyable, because the algorithms can be very clearly expressed, and the code is usually very concise and simple. This is true because awk does so much for you.

It should be noted that these programs are not necessarily intended to replace the installed versions on your system. Nor may all of these programs be fully compliant with the most recent POSIX standard. This is not a problem; their purpose is to illustrate awk language programming for "real world" tasks.

The programs are presented in alphabetical order.

11.2.1 Cutting out Fields and Columns

The cut utility selects, or "cuts," characters or fields from its standard input and sends them to its standard output. Fields are separated by TABs by default, but you may supply a command-line option to change the field *delimiter* (i.e., the field-separator character). cut's definition of fields is less general than awk's.

A common use of `cut` might be to pull out just the login name of logged-on users from the output of `who`. For example, the following pipeline generates a sorted, unique list of the logged-on users:

```
who | cut -c1-8 | sort | uniq
```

The options for `cut` are:

`-c list` Use *list* as the list of characters to cut out. Items within the list may be separated by commas, and ranges of characters can be separated with dashes. The list '`1-8,15,22-35`' specifies characters 1 through 8, 15, and 22 through 35.

`-f list` Use *list* as the list of fields to cut out.

`-d delim` Use *delim* as the field-separator character instead of the TAB character.

`-s` Suppress printing of lines that do not contain the field delimiter.

The `awk` implementation of `cut` uses the `getopt()` library function (see Section 10.4 [Processing Command-Line Options], page 216) and the `join()` library function (see Section 10.2.6 [Merging an Array into a String], page 209).

The program begins with a comment describing the options, the library functions needed, and a `usage()` function that prints out a usage message and exits. `usage()` is called if invalid arguments are supplied:

```
# cut.awk --- implement cut in awk

# Options:
#    -f list     Cut fields
#    -d c        Field delimiter character
#    -c list     Cut characters
#
#    -s          Suppress lines without the delimiter
#
# Requires getopt() and join() library functions

function usage(    e1, e2)
{
    e1 = "usage: cut [-f list] [-d c] [-s] [files...]"
    e2 = "usage: cut [-c list] [files...]"
    print e1 > "/dev/stderr"
    print e2 > "/dev/stderr"
    exit 1
}
```

The variables `e1` and `e2` are used so that the function fits nicely on the page.

Next comes a `BEGIN` rule that parses the command-line options. It sets `FS` to a single TAB character, because that is `cut`'s default field separator. The rule then sets the output field separator to be the same as the input field separator. A loop using `getopt()` steps through the command-line options. Exactly one of the variables `by_fields` or `by_chars` is set to true, to indicate that processing should be done by fields or by characters, respectively. When cutting by characters, the output field separator is set to the null string:

```
BEGIN    \
{
    FS = "\t"    # default
    OFS = FS
    while ((c = getopt(ARGC, ARGV, "sf:c:d:")) != -1) {
        if (c == "f") {
            by_fields = 1
            fieldlist = Optarg
        } else if (c == "c") {
            by_chars = 1
            fieldlist = Optarg
            OFS = ""
        } else if (c == "d") {
            if (length(Optarg) > 1) {
                printf("Using first character of %s" \
                       " for delimiter\n", Optarg) > "/dev/stderr"
                Optarg = substr(Optarg, 1, 1)
            }
            FS = Optarg
            OFS = FS
            if (FS == " ")    # defeat awk semantics
                FS = "[ ]"
        } else if (c == "s")
            suppress++
        else
            usage()
    }

    # Clear out options
    for (i = 1; i < Optind; i++)
        ARGV[i] = ""
```

The code must take special care when the field delimiter is a space. Using a single space (`" "`) for the value of `FS` is incorrect—`awk` would separate fields with runs of spaces, TABs, and/or newlines, and we want them to be separated with individual spaces. Also remember that after `getopt()` is through (as described in Section 10.4 [Processing Command-Line Options], page 216), we have to clear out all the elements of `ARGV` from 1 to `Optind`, so that `awk` does not try to process the command-line options as file names.

After dealing with the command-line options, the program verifies that the options make sense. Only one or the other of `-c` and `-f` should be used, and both require a field list. Then the program calls either `set_fieldlist()` or `set_charlist()` to pull apart the list of fields or characters:

```
    if (by_fields && by_chars)
        usage()

    if (by_fields == 0 && by_chars == 0)
        by_fields = 1    # default
```

```
    if (fieldlist == "") {
        print "cut: needs list for -c or -f" > "/dev/stderr"
        exit 1
    }

    if (by_fields)
        set_fieldlist()
    else
        set_charlist()
}
```

set_fieldlist() splits the field list apart at the commas into an array. Then, for each element of the array, it looks to see if the element is actually a range, and if so, splits it apart. The function checks the range to make sure that the first number is smaller than the second. Each number in the list is added to the flist array, which simply lists the fields that will be printed. Normal field splitting is used. The program lets awk handle the job of doing the field splitting:

```
function set_fieldlist(        n, m, i, j, k, f, g)
{
    n = split(fieldlist, f, ",")
    j = 1    # index in flist
    for (i = 1; i <= n; i++) {
        if (index(f[i], "-") != 0) { # a range
            m = split(f[i], g, "-")
            if (m != 2 || g[1] >= g[2]) {
                printf("bad field list: %s\n",
                                  f[i]) > "/dev/stderr"
                exit 1
            }
            for (k = g[1]; k <= g[2]; k++)
                flist[j++] = k
        } else
            flist[j++] = f[i]
    }
    nfields = j - 1
}
```

The set_charlist() function is more complicated than set_fieldlist(). The idea here is to use gawk's FIELDWIDTHS variable (see Section 4.6 [Reading Fixed-Width Data], page 67), which describes constant-width input. When using a character list, that is exactly what we have.

Setting up FIELDWIDTHS is more complicated than simply listing the fields that need to be printed. We have to keep track of the fields to print and also the intervening characters that have to be skipped. For example, suppose you wanted characters 1 through 8, 15, and 22 through 35. You would use '-c 1-8,15,22-35'. The necessary value for FIELDWIDTHS is "8 6 1 6 14". This yields five fields, and the fields to print are $1, $3, and $5. The intermediate fields are *filler*, which is stuff in between the desired data. `flist` lists the fields to print, and `t` tracks the complete field list, including filler fields:

```
function set_charlist(    field, i, j, f, g, t,
                          filler, last, len)
{
    field = 1   # count total fields
    n = split(fieldlist, f, ",")
    j = 1       # index in flist
    for (i = 1; i <= n; i++) {
        if (index(f[i], "-") != 0) { # range
            m = split(f[i], g, "-")
            if (m != 2 || g[1] >= g[2]) {
                printf("bad character list: %s\n",
                               f[i]) > "/dev/stderr"
                exit 1
            }
            len = g[2] - g[1] + 1
            if (g[1] > 1)  # compute length of filler
                filler = g[1] - last - 1
            else
                filler = 0
            if (filler)
                t[field++] = filler
            t[field++] = len  # length of field
            last = g[2]
            flist[j++] = field - 1
        } else {
            if (f[i] > 1)
                filler = f[i] - last - 1
            else
                filler = 0
            if (filler)
                t[field++] = filler
            t[field++] = 1
            last = f[i]
            flist[j++] = field - 1
        }
    }
    FIELDWIDTHS = join(t, 1, field - 1)
    nfields = j - 1
}
```

Next is the rule that actually processes the data. If the `-s` option is given, then `suppress` is true. The first `if` statement makes sure that the input record does have the field separator. If `cut` is processing fields, `suppress` is true, and the field separator character is not in the record, then the record is skipped.

If the record is valid, then gawk has split the data into fields, either using the character in FS or using fixed-length fields and FIELDWIDTHS. The loop goes through the list of fields that should be printed. The corresponding field is printed if it contains data. If the next field also has data, then the separator character is written out between the fields:

```
{
    if (by_fields && suppress && index($0, FS) == 0)
        next

    for (i = 1; i <= nfields; i++) {
        if ($flist[i] != "") {
            printf "%s", $flist[i]
            if (i < nfields && $flist[i+1] != "")
                printf "%s", OFS
        }
    }
    print ""
}
```

This version of cut relies on gawk's FIELDWIDTHS variable to do the character-based cutting. While it is possible in other awk implementations to use substr() (see Section 9.1.3 [String-Manipulation Functions], page 161), it is also extremely painful. The FIELDWIDTHS variable supplies an elegant solution to the problem of picking the input line apart by characters.

11.2.2 Searching for Regular Expressions in Files

The egrep utility searches files for patterns. It uses regular expressions that are almost identical to those available in awk (see Chapter 3 [Regular Expressions], page 43). You invoke it as follows:

egrep [*options*] *'pattern' files ...*

The *pattern* is a regular expression. In typical usage, the regular expression is quoted to prevent the shell from expanding any of the special characters as file name wildcards. Normally, egrep prints the lines that matched. If multiple file names are provided on the command line, each output line is preceded by the name of the file and a colon.

The options to egrep are as follows:

-c
: Print out a count of the lines that matched the pattern, instead of the lines themselves.

-s
: Be silent. No output is produced and the exit value indicates whether the pattern was matched.

-v
: Invert the sense of the test. egrep prints the lines that do *not* match the pattern and exits successfully if the pattern is not matched.

-i
: Ignore case distinctions in both the pattern and the input data.

-l
: Only print (list) the names of the files that matched, not the lines that matched.

-e *pattern*
: Use *pattern* as the regexp to match. The purpose of the -e option is to allow patterns that start with a '-'.

This version uses the `getopt()` library function (see Section 10.4 [Processing Command-Line Options], page 216) and the file transition library program (see Section 10.3.1 [Noting Data File Boundaries], page 212).

The program begins with a descriptive comment and then a `BEGIN` rule that processes the command-line arguments with `getopt()`. The `-i` (ignore case) option is particularly easy with `gawk`; we just use the `IGNORECASE` built-in variable (see Section 7.5 [Built-in Variables], page 134):

```
# egrep.awk --- simulate egrep in awk
#
# Options:
#    -c    count of lines
#    -s    silent - use exit value
#    -v    invert test, success if no match
#    -i    ignore case
#    -l    print filenames only
#    -e    argument is pattern
#
# Requires getopt and file transition library functions

BEGIN {
    while ((c = getopt(ARGC, ARGV, "ce:svil")) != -1) {
        if (c == "c")
            count_only++
        else if (c == "s")
            no_print++
        else if (c == "v")
            invert++
        else if (c == "i")
            IGNORECASE = 1
        else if (c == "l")
            filenames_only++
        else if (c == "e")
            pattern = Optarg
        else
            usage()
    }
```

Next comes the code that handles the `egrep`-specific behavior. If no pattern is supplied with `-e`, the first nonoption on the command line is used. The `awk` command-line arguments up to `ARGV[Optind]` are cleared, so that `awk` won't try to process them as files. If no files are specified, the standard input is used, and if multiple files are specified, we make sure to note this so that the file names can precede the matched lines in the output:

```
    if (pattern == "")
        pattern = ARGV[Optind++]

    for (i = 1; i < Optind; i++)
        ARGV[i] = ""
```

```
        if (Optind >= ARGC) {
            ARGV[1] = "-"
            ARGC = 2
        } else if (ARGC - Optind > 1)
            do_filenames++

    #    if (IGNORECASE)
    #        pattern = tolower(pattern)
    }
```

The last two lines are commented out, since they are not needed in gawk. They should be uncommented if you have to use another version of awk.

The next set of lines should be uncommented if you are not using gawk. This rule translates all the characters in the input line into lowercase if the -i option is specified.[1] The rule is commented out since it is not necessary with gawk:

```
#{
#    if (IGNORECASE)
#        $0 = tolower($0)
#}
```

The beginfile() function is called by the rule in ftrans.awk when each new file is processed. In this case, it is very simple; all it does is initialize a variable fcount to zero. fcount tracks how many lines in the current file matched the pattern. Naming the parameter junk shows we know that beginfile() is called with a parameter, but that we're not interested in its value:

```
function beginfile(junk)
{
    fcount = 0
}
```

The endfile() function is called after each file has been processed. It affects the output only when the user wants a count of the number of lines that matched. no_print is true only if the exit status is desired. count_only is true if line counts are desired. egrep therefore only prints line counts if printing and counting are enabled. The output format must be adjusted depending upon the number of files to process. Finally, fcount is added to total, so that we know the total number of lines that matched the pattern:

```
function endfile(file)
{
    if (! no_print && count_only) {
        if (do_filenames)
            print file ":" fcount
        else
            print fcount
    }

    total += fcount
```

[1] It also introduces a subtle bug; if a match happens, we output the translated line, not the original.

```
}
```

The following rule does most of the work of matching lines. The variable `matches` is true if the line matched the pattern. If the user wants lines that did not match, the sense of `matches` is inverted using the '`!`' operator. `fcount` is incremented with the value of `matches`, which is either one or zero, depending upon a successful or unsuccessful match. If the line does not match, the `next` statement just moves on to the next record.

A number of additional tests are made, but they are only done if we are not counting lines. First, if the user only wants exit status (`no_print` is true), then it is enough to know that *one* line in this file matched, and we can skip on to the next file with `nextfile`. Similarly, if we are only printing file names, we can print the file name, and then skip to the next file with `nextfile`. Finally, each line is printed, with a leading file name and colon if necessary:

```
{
    matches = ($0 ~ pattern)
    if (invert)
        matches = ! matches

    fcount += matches    # 1 or 0

    if (! matches)
        next

    if (! count_only) {
        if (no_print)
            nextfile

        if (filenames_only) {
            print FILENAME
            nextfile
        }

        if (do_filenames)
            print FILENAME ":" $0
        else
            print
    }
}
```

The `END` rule takes care of producing the correct exit status. If there are no matches, the exit status is one; otherwise it is zero:

```
END    \
{
    if (total == 0)
        exit 1
    exit 0
}
```

The `usage()` function prints a usage message in case of invalid options, and then exits:

```
function usage(    e)
{
    e = "Usage: egrep [-csvil] [-e pat] [files ...]"
    e = e "\n\tegrep [-csvil] pat [files ...]"
    print e > "/dev/stderr"
    exit 1
}
```

The variable `e` is used so that the function fits nicely on the printed page.

Just a note on programming style: you may have noticed that the `END` rule uses backslash continuation, with the open brace on a line by itself. This is so that it more closely resembles the way functions are written. Many of the examples in this chapter use this style. You can decide for yourself if you like writing your `BEGIN` and `END` rules this way or not.

11.2.3 Printing out User Information

The `id` utility lists a user's real and effective user ID numbers, real and effective group ID numbers, and the user's group set, if any. `id` only prints the effective user ID and group ID if they are different from the real ones. If possible, `id` also supplies the corresponding user and group names. The output might look like this:

```
$ id
⊣ uid=500(arnold) gid=500(arnold) groups=6(disk),7(lp),19(floppy)
```

This information is part of what is provided by `gawk`'s `PROCINFO` array (see Section 7.5 [Built-in Variables], page 134). However, the `id` utility provides a more palatable output than just individual numbers.

Here is a simple version of `id` written in `awk`. It uses the user database library functions (see Section 10.5 [Reading the User Database], page 221) and the group database library functions (see Section 10.6 [Reading the Group Database], page 225):

The program is fairly straightforward. All the work is done in the `BEGIN` rule. The user and group ID numbers are obtained from `PROCINFO`. The code is repetitive. The entry in the user database for the real user ID number is split into parts at the '`:`'. The name is the first field. Similar code is used for the effective user ID number and the group numbers:

```
# id.awk --- implement id in awk
#
# Requires user and group library functions
# output is:
# uid=12(foo) euid=34(bar) gid=3(baz) \
#             egid=5(blat) groups=9(nine),2(two),1(one)

BEGIN    \
{
    uid = PROCINFO["uid"]
    euid = PROCINFO["euid"]
    gid = PROCINFO["gid"]
    egid = PROCINFO["egid"]

    printf("uid=%d", uid)
```

```
    pw = getpwuid(uid)
    if (pw != "") {
        split(pw, a, ":")
        printf("(%s)", a[1])
    }

    if (euid != uid) {
        printf(" euid=%d", euid)
        pw = getpwuid(euid)
        if (pw != "") {
            split(pw, a, ":")
            printf("(%s)", a[1])
        }
    }

    printf(" gid=%d", gid)
    pw = getgrgid(gid)
    if (pw != "") {
        split(pw, a, ":")
        printf("(%s)", a[1])
    }

    if (egid != gid) {
        printf(" egid=%d", egid)
        pw = getgrgid(egid)
        if (pw != "") {
            split(pw, a, ":")
            printf("(%s)", a[1])
        }
    }

    for (i = 1; ("group" i) in PROCINFO; i++) {
        if (i == 1)
            printf(" groups=")
        group = PROCINFO["group" i]
        printf("%d", group)
        pw = getgrgid(group)
        if (pw != "") {
            split(pw, a, ":")
            printf("(%s)", a[1])
        }
        if (("group" (i+1)) in PROCINFO)
            printf(",")
    }

    print ""
}
```

The test in the `for` loop is worth noting. Any supplementary groups in the `PROCINFO` array have the indices `"group1"` through `"groupN"` for some *N*, i.e., the total number of supplementary groups. However, we don't know in advance how many of these groups there are.

This loop works by starting at one, concatenating the value with `"group"`, and then using `in` to see if that value is in the array. Eventually, `i` is incremented past the last group in the array and the loop exits.

The loop is also correct if there are *no* supplementary groups; then the condition is false the first time it's tested, and the loop body never executes.

11.2.4 Splitting a Large File into Pieces

The `split` program splits large text files into smaller pieces. Usage is as follows:[2]

split [-*count*] file [*prefix*]

By default, the output files are named `xaa`, `xab`, and so on. Each file has 1000 lines in it, with the likely exception of the last file. To change the number of lines in each file, supply a number on the command line preceded with a minus; e.g., '`-500`' for files with 500 lines in them instead of 1000. To change the name of the output files to something like `myfileaa`, `myfileab`, and so on, supply an additional argument that specifies the file name prefix.

Here is a version of `split` in `awk`. It uses the `ord()` and `chr()` functions presented in Section 10.2.5 [Translating Between Characters and Numbers], page 207.

The program first sets its defaults, and then tests to make sure there are not too many arguments. It then looks at each argument in turn. The first argument could be a minus sign followed by a number. If it is, this happens to look like a negative number, so it is made positive, and that is the count of lines. The data file name is skipped over and the final argument is used as the prefix for the output file names:

```
# split.awk --- do split in awk
#
# Requires ord() and chr() library functions
# usage: split [-num] [file] [outname]

BEGIN {
    outfile = "x"    # default
    count = 1000
    if (ARGC > 4)
        usage()

    i = 1
    if (ARGV[i] ~ /^-[[:digit:]]+$/) {
        count = -ARGV[i]
        ARGV[i] = ""
        i++
    }
    # test argv in case reading from stdin instead of file
```

[2] This is the traditional usage. The POSIX usage is different, but not relevant for what the program aims to demonstrate.

```
        if (i in ARGV)
            i++    # skip data file name
        if (i in ARGV) {
            outfile = ARGV[i]
            ARGV[i] = ""
        }

        s1 = s2 = "a"
        out = (outfile s1 s2)
    }
```

The next rule does most of the work. `tcount` (temporary count) tracks how many lines have been printed to the output file so far. If it is greater than `count`, it is time to close the current file and start a new one. `s1` and `s2` track the current suffixes for the file name. If they are both '`z`', the file is just too big. Otherwise, `s1` moves to the next letter in the alphabet and `s2` starts over again at '`a`':

```
    {
        if (++tcount > count) {
            close(out)
            if (s2 == "z") {
                if (s1 == "z") {
                    printf("split: %s is too large to split\n",
                           FILENAME) > "/dev/stderr"
                    exit 1
                }
                s1 = chr(ord(s1) + 1)
                s2 = "a"
            }
            else
                s2 = chr(ord(s2) + 1)
            out = (outfile s1 s2)
            tcount = 1
        }
        print > out
    }
```

The `usage()` function simply prints an error message and exits:

```
    function usage(   e)
    {
        e = "usage: split [-num] [file] [outname]"
        print e > "/dev/stderr"
        exit 1
    }
```

The variable `e` is used so that the function fits nicely on the page.

This program is a bit sloppy; it relies on `awk` to automatically close the last file instead of doing it in an `END` rule. It also assumes that letters are contiguous in the character set, which isn't true for EBCDIC systems.

11.2.5 Duplicating Output into Multiple Files

The `tee` program is known as a "pipe fitting." `tee` copies its standard input to its standard output and also duplicates it to the files named on the command line. Its usage is as follows:

```
tee [-a] file ...
```

The `-a` option tells `tee` to append to the named files, instead of truncating them and starting over.

The `BEGIN` rule first makes a copy of all the command-line arguments into an array named `copy`. `ARGV[0]` is not copied, since it is not needed. `tee` cannot use `ARGV` directly, since `awk` attempts to process each file name in `ARGV` as input data.

If the first argument is `-a`, then the flag variable `append` is set to true, and both `ARGV[1]` and `copy[1]` are deleted. If `ARGC` is less than two, then no file names were supplied and `tee` prints a usage message and exits. Finally, `awk` is forced to read the standard input by setting `ARGV[1]` to `"-"` and `ARGC` to two:

```
# tee.awk --- tee in awk
#
# Copy standard input to all named output files.
# Append content if -a option is supplied.
#
BEGIN    \
{
    for (i = 1; i < ARGC; i++)
        copy[i] = ARGV[i]

    if (ARGV[1] == "-a") {
        append = 1
        delete ARGV[1]
        delete copy[1]
        ARGC--
    }
    if (ARGC < 2) {
        print "usage: tee [-a] file ..." > "/dev/stderr"
        exit 1
    }
    ARGV[1] = "-"
    ARGC = 2
}
```

The following single rule does all the work. Since there is no pattern, it is executed for each line of input. The body of the rule simply prints the line into each file on the command line, and then to the standard output:

```
{
    # moving the if outside the loop makes it run faster
    if (append)
        for (i in copy)
            print >> copy[i]
    else
```

```
            for (i in copy)
                print > copy[i]
        print
    }
```

It is also possible to write the loop this way:

```
    for (i in copy)
        if (append)
            print >> copy[i]
        else
            print > copy[i]
```

This is more concise but it is also less efficient. The 'if' is tested for each record and for each output file. By duplicating the loop body, the 'if' is only tested once for each input record. If there are N input records and M output files, the first method only executes N 'if' statements, while the second executes $N*M$ 'if' statements.

Finally, the `END` rule cleans up by closing all the output files:

```
    END    \
    {
        for (i in copy)
            close(copy[i])
    }
```

11.2.6 Printing Nonduplicated Lines of Text

The `uniq` utility reads sorted lines of data on its standard input, and by default removes duplicate lines. In other words, it only prints unique lines—hence the name. `uniq` has a number of options. The usage is as follows:

`uniq` [-udc [-*n*]] [+*n*] [*input file* [*output file*]]

The options for `uniq` are:

`-d` Print only repeated lines.

`-u` Print only nonrepeated lines.

`-c` Count lines. This option overrides `-d` and `-u`. Both repeated and nonrepeated lines are counted.

`-n` Skip *n* fields before comparing lines. The definition of fields is similar to `awk`'s default: nonwhitespace characters separated by runs of spaces and/or TABs.

`+n` Skip *n* characters before comparing lines. Any fields specified with '-*n*' are skipped first.

input file
Data is read from the input file named on the command line, instead of from the standard input.

output file
The generated output is sent to the named output file, instead of to the standard output.

Normally `uniq` behaves as if both the `-d` and `-u` options are provided.

`uniq` uses the `getopt()` library function (see Section 10.4 [Processing Command-Line Options], page 216) and the `join()` library function (see Section 10.2.6 [Merging an Array into a String], page 209).

The program begins with a `usage()` function and then a brief outline of the options and their meanings in comments. The `BEGIN` rule deals with the command-line arguments and options. It uses a trick to get `getopt()` to handle options of the form '`-25`', treating such an option as the option letter '`2`' with an argument of '`5`'. If indeed two or more digits are supplied (`Optarg` looks like a number), `Optarg` is concatenated with the option digit and then the result is added to zero to make it into a number. If there is only one digit in the option, then `Optarg` is not needed. In this case, `Optind` must be decremented so that `getopt()` processes it next time. This code is admittedly a bit tricky.

If no options are supplied, then the default is taken, to print both repeated and nonrepeated lines. The output file, if provided, is assigned to `outputfile`. Early on, `outputfile` is initialized to the standard output, `/dev/stdout`:

```
# uniq.awk --- do uniq in awk
#
# Requires getopt() and join() library functions

function usage(    e)
{
    e = "Usage: uniq [-udc [-n]] [+n] [ in [ out ]]"
    print e > "/dev/stderr"
    exit 1
}

# -c    count lines. overrides -d and -u
# -d    only repeated lines
# -u    only nonrepeated lines
# -n    skip n fields
# +n    skip n characters, skip fields first

BEGIN   \
{
    count = 1
    outputfile = "/dev/stdout"
    opts = "udc0:1:2:3:4:5:6:7:8:9:"
    while ((c = getopt(ARGC, ARGV, opts)) != -1) {
        if (c == "u")
            non_repeated_only++
        else if (c == "d")
            repeated_only++
        else if (c == "c")
            do_count++
        else if (index("0123456789", c) != 0) {
            # getopt requires args to options
```

```
                # this messes us up for things like -5
                if (Optarg ~ /^[[:digit:]]+$/)
                    fcount = (c Optarg) + 0
                else {
                    fcount = c + 0
                    Optind--
                }
            } else
                usage()
        }

        if (ARGV[Optind] ~ /^\+[[:digit:]]+$/) {
            charcount = substr(ARGV[Optind], 2) + 0
            Optind++
        }

        for (i = 1; i < Optind; i++)
            ARGV[i] = ""

        if (repeated_only == 0 && non_repeated_only == 0)
            repeated_only = non_repeated_only = 1

        if (ARGC - Optind == 2) {
            outputfile = ARGV[ARGC - 1]
            ARGV[ARGC - 1] = ""
        }
    }
```

The following function, `are_equal()`, compares the current line, `$0`, to the previous line, `last`. It handles skipping fields and characters. If no field count and no character count are specified, `are_equal()` simply returns one or zero depending upon the result of a simple string comparison of `last` and `$0`. Otherwise, things get more complicated. If fields have to be skipped, each line is broken into an array using `split()` (see Section 9.1.3 [String-Manipulation Functions], page 161); the desired fields are then joined back into a line using `join()`. The joined lines are stored in `clast` and `cline`. If no fields are skipped, `clast` and `cline` are set to `last` and `$0`, respectively. Finally, if characters are skipped, `substr()` is used to strip off the leading `charcount` characters in `clast` and `cline`. The two strings are then compared and `are_equal()` returns the result:

```
    function are_equal(    n, m, clast, cline, alast, aline)
    {
        if (fcount == 0 && charcount == 0)
            return (last == $0)

        if (fcount > 0) {
            n = split(last, alast)
            m = split($0, aline)
            clast = join(alast, fcount+1, n)
```

```
            cline = join(aline, fcount+1, m)
        } else {
            clast = last
            cline = $0
        }
        if (charcount) {
            clast = substr(clast, charcount + 1)
            cline = substr(cline, charcount + 1)
        }

        return (clast == cline)
    }
```

The following two rules are the body of the program. The first one is executed only for the very first line of data. It sets `last` equal to `$0`, so that subsequent lines of text have something to be compared to.

The second rule does the work. The variable `equal` is one or zero, depending upon the results of `are_equal()`'s comparison. If `uniq` is counting repeated lines, and the lines are equal, then it increments the `count` variable. Otherwise, it prints the line and resets `count`, since the two lines are not equal.

If `uniq` is not counting, and if the lines are equal, `count` is incremented. Nothing is printed, since the point is to remove duplicates. Otherwise, if `uniq` is counting repeated lines and more than one line is seen, or if `uniq` is counting nonrepeated lines and only one line is seen, then the line is printed, and `count` is reset.

Finally, similar logic is used in the `END` rule to print the final line of input data:

```
    NR == 1 {
        last = $0
        next
    }

    {
        equal = are_equal()

        if (do_count) {    # overrides -d and -u
            if (equal)
                count++
            else {
                printf("%4d %s\n", count, last) > outputfile
                last = $0
                count = 1    # reset
            }
            next
        }

        if (equal)
            count++
        else {
```

```
            if ((repeated_only && count > 1) ||
                (non_repeated_only && count == 1))
                    print last > outputfile
            last = $0
            count = 1
        }
    }

    END {
        if (do_count)
            printf("%4d %s\n", count, last) > outputfile
        else if ((repeated_only && count > 1) ||
                (non_repeated_only && count == 1))
            print last > outputfile
        close(outputfile)
    }
```

11.2.7 Counting Things

The wc (word count) utility counts lines, words, and characters in one or more input files. Its usage is as follows:

wc [-lwc] [*files* ...]

If no files are specified on the command line, wc reads its standard input. If there are multiple files, it also prints total counts for all the files. The options and their meanings are shown in the following list:

-l Count only lines.

-w Count only words. A "word" is a contiguous sequence of nonwhitespace characters, separated by spaces and/or TABs. Luckily, this is the normal way awk separates fields in its input data.

-c Count only characters.

Implementing wc in awk is particularly elegant, since awk does a lot of the work for us; it splits lines into words (i.e., fields) and counts them, it counts lines (i.e., records), and it can easily tell us how long a line is.

This program uses the getopt() library function (see Section 10.4 [Processing Command-Line Options], page 216) and the file-transition functions (see Section 10.3.1 [Noting Data File Boundaries], page 212).

This version has one notable difference from traditional versions of wc: it always prints the counts in the order lines, words, and characters. Traditional versions note the order of the -l, -w, and -c options on the command line, and print the counts in that order.

The BEGIN rule does the argument processing. The variable print_total is true if more than one file is named on the command line:

```
    # wc.awk --- count lines, words, characters

    # Options:
    #    -l    only count lines
```

```
#    -w    only count words
#    -c    only count characters
#
# Default is to count lines, words, characters
#
# Requires getopt() and file transition library functions

BEGIN {
    # let getopt() print a message about
    # invalid options. we ignore them
    while ((c = getopt(ARGC, ARGV, "lwc")) != -1) {
        if (c == "l")
            do_lines = 1
        else if (c == "w")
            do_words = 1
        else if (c == "c")
            do_chars = 1
    }
    for (i = 1; i < Optind; i++)
        ARGV[i] = ""

    # if no options, do all
    if (! do_lines && ! do_words && ! do_chars)
        do_lines = do_words = do_chars = 1

    print_total = (ARGC - i > 2)
}
```

The `beginfile()` function is simple; it just resets the counts of lines, words, and characters to zero, and saves the current file name in `fname`:

```
function beginfile(file)
{
    lines = words = chars = 0
    fname = FILENAME
}
```

The `endfile()` function adds the current file's numbers to the running totals of lines, words, and characters.[3] It then prints out those numbers for the file that was just read. It relies on `beginfile()` to reset the numbers for the following data file:

```
function endfile(file)
{
    tlines += lines
    twords += words
    tchars += chars
    if (do_lines)
```

[3] `wc` can't just use the value of `FNR` in `endfile()`. If you examine the code in Section 10.3.1 [Noting Data File Boundaries], page 212, you will see that `FNR` has already been reset by the time `endfile()` is called.

```
        printf "\t%d", lines
    if (do_words)
        printf "\t%d", words
    if (do_chars)
        printf "\t%d", chars
    printf "\t%s\n", fname
}
```

There is one rule that is executed for each line. It adds the length of the record, plus one, to `chars`.[4] Adding one plus the record length is needed because the newline character separating records (the value of `RS`) is not part of the record itself, and thus not included in its length. Next, `lines` is incremented for each line read, and `words` is incremented by the value of `NF`, which is the number of "words" on this line:

```
# do per line
{
    chars += length($0) + 1    # get newline
    lines++
    words += NF
}
```

Finally, the `END` rule simply prints the totals for all the files:

```
END {
    if (print_total) {
        if (do_lines)
            printf "\t%d", tlines
        if (do_words)
            printf "\t%d", twords
        if (do_chars)
            printf "\t%d", tchars
        print "\ttotal"
    }
}
```

11.3 A Grab Bag of awk Programs

This section is a large "grab bag" of miscellaneous programs. We hope you find them both interesting and enjoyable.

11.3.1 Finding Duplicated Words in a Document

A common error when writing large amounts of prose is to accidentally duplicate words. Typically you will see this in text as something like "the the program does the following..." When the text is online, often the duplicated words occur at the end of one line and the the beginning of another, making them very difficult to spot.

This program, `dupword.awk`, scans through a file one line at a time and looks for adjacent occurrences of the same word. It also saves the last word on a line (in the variable `prev`) for comparison with the first word on the next line.

[4] Since `gawk` understands multibyte locales, this code counts characters, not bytes.

The first two statements make sure that the line is all lowercase, so that, for example, "The" and "the" compare equal to each other. The next statement replaces nonalphanumeric and nonwhitespace characters with spaces, so that punctuation does not affect the comparison either. The characters are replaced with spaces so that formatting controls don't create nonsense words (e.g., the Texinfo '@code{NF}' becomes 'codeNF' if punctuation is simply deleted). The record is then resplit into fields, yielding just the actual words on the line, and ensuring that there are no empty fields.

If there are no fields left after removing all the punctuation, the current record is skipped. Otherwise, the program loops through each word, comparing it to the previous one:

```
# dupword.awk --- find duplicate words in text
{
    $0 = tolower($0)
    gsub(/[^[:alnum:][:blank:]]/, " ");
    $0 = $0         # re-split
    if (NF == 0)
        next
    if ($1 == prev)
        printf("%s:%d: duplicate %s\n",
            FILENAME, FNR, $1)
    for (i = 2; i <= NF; i++)
        if ($i == $(i-1))
            printf("%s:%d: duplicate %s\n",
                FILENAME, FNR, $i)
    prev = $NF
}
```

11.3.2 An Alarm Clock Program

Nothing cures insomnia like a ringing alarm clock.
Arnold Robbins

The following program is a simple "alarm clock" program. You give it a time of day and an optional message. At the specified time, it prints the message on the standard output. In addition, you can give it the number of times to repeat the message as well as a delay between repetitions.

This program uses the `getlocaltime()` function from Section 10.2.7 [Managing the Time of Day], page 209.

All the work is done in the `BEGIN` rule. The first part is argument checking and setting of defaults: the delay, the count, and the message to print. If the user supplied a message without the ASCII BEL character (known as the "alert" character, `"\a"`), then it is added to the message. (On many systems, printing the ASCII BEL generates an audible alert. Thus when the alarm goes off, the system calls attention to itself in case the user is not looking at the computer.) Just for a change, this program uses a `switch` statement (see Section 7.4.5 [The switch Statement], page 129), but the processing could be done with a series of `if-else` statements instead. Here is the program:

```
# alarm.awk --- set an alarm
#
```

```
# Requires getlocaltime() library function
# usage: alarm time [ "message" [ count [ delay ] ] ]

BEGIN    \
{
    # Initial argument sanity checking
    usage1 = "usage: alarm time ['message' [count [delay]]]"
    usage2 = sprintf("\t(%s) time ::= hh:mm", ARGV[1])

    if (ARGC < 2) {
        print usage1 > "/dev/stderr"
        print usage2 > "/dev/stderr"
        exit 1
    }
    switch (ARGC) {
    case 5:
        delay = ARGV[4] + 0
        # fall through
    case 4:
        count = ARGV[3] + 0
        # fall through
    case 3:
        message = ARGV[2]
        break
    default:
        if (ARGV[1] !~ /[[:digit:]]?[[:digit:]]:[[:digit:]]{2}/) {
            print usage1 > "/dev/stderr"
            print usage2 > "/dev/stderr"
            exit 1
        }
        break
    }

    # set defaults for once we reach the desired time
    if (delay == 0)
        delay = 180    # 3 minutes
    if (count == 0)
        count = 5
    if (message == "")
        message = sprintf("\aIt is now %s!\a", ARGV[1])
    else if (index(message, "\a") == 0)
        message = "\a" message "\a"
```

The next section of code turns the alarm time into hours and minutes, converts it (if necessary) to a 24-hour clock, and then turns that time into a count of the seconds since midnight. Next it turns the current time into a count of seconds since midnight. The difference between the two is how long to wait before setting off the alarm:

```
# split up alarm time
split(ARGV[1], atime, ":")
hour = atime[1] + 0    # force numeric
minute = atime[2] + 0  # force numeric

# get current broken down time
getlocaltime(now)

# if time given is 12-hour hours and it's after that
# hour, e.g., `alarm 5:30' at 9 a.m. means 5:30 p.m.,
# then add 12 to real hour
if (hour < 12 && now["hour"] > hour)
    hour += 12

# set target time in seconds since midnight
target = (hour * 60 * 60) + (minute * 60)

# get current time in seconds since midnight
current = (now["hour"] * 60 * 60) + \
           (now["minute"] * 60) + now["second"]

# how long to sleep for
naptime = target - current
if (naptime <= 0) {
    print "time is in the past!" > "/dev/stderr"
    exit 1
}
```

Finally, the program uses the `system()` function (see Section 9.1.4 [Input/Output Functions], page 173) to call the `sleep` utility. The `sleep` utility simply pauses for the given number of seconds. If the exit status is not zero, the program assumes that `sleep` was interrupted and exits. If `sleep` exited with an OK status (zero), then the program prints the message in a loop, again using `sleep` to delay for however many seconds are necessary:

```
# zzzzzz..... go away if interrupted
if (system(sprintf("sleep %d", naptime)) != 0)
    exit 1

# time to notify!
command = sprintf("sleep %d", delay)
for (i = 1; i <= count; i++) {
    print message
    # if sleep command interrupted, go away
    if (system(command) != 0)
        break
}

exit 0
```

```
}
```

11.3.3 Transliterating Characters

The system `tr` utility transliterates characters. For example, it is often used to map uppercase letters into lowercase for further processing:

```
generate data | tr 'A-Z' 'a-z' | process data ...
```

`tr` requires two lists of characters.[5] When processing the input, the first character in the first list is replaced with the first character in the second list, the second character in the first list is replaced with the second character in the second list, and so on. If there are more characters in the "from" list than in the "to" list, the last character of the "to" list is used for the remaining characters in the "from" list.

Some time ago, a user proposed that a transliteration function should be added to `gawk`. The following program was written to prove that character transliteration could be done with a user-level function. This program is not as complete as the system `tr` utility but it does most of the job.

The `translate` program demonstrates one of the few weaknesses of standard `awk`: dealing with individual characters is very painful, requiring repeated use of the `substr()`, `index()`, and `gsub()` built-in functions (see Section 9.1.3 [String-Manipulation Functions], page 161).[6] There are two functions. The first, `stranslate()`, takes three arguments:

`from` A list of characters from which to translate.

`to` A list of characters to which to translate.

`target` The string on which to do the translation.

Associative arrays make the translation part fairly easy. `t_ar` holds the "to" characters, indexed by the "from" characters. Then a simple loop goes through `from`, one character at a time. For each character in `from`, if the character appears in `target`, it is replaced with the corresponding `to` character.

The `translate()` function simply calls `stranslate()` using `$0` as the target. The main program sets two global variables, `FROM` and `TO`, from the command line, and then changes `ARGV` so that `awk` reads from the standard input.

Finally, the processing rule simply calls `translate()` for each record:

```
# translate.awk --- do tr-like stuff
# Bugs: does not handle things like: tr A-Z a-z, it has
# to be spelled out. However, if `to' is shorter than `from',
# the last character in `to' is used for the rest of `from'.

function stranslate(from, to, target,     lf, lt, ltarget, t_ar, i, c,
                                                               result)
{
```

[5] On some older systems, `tr` may require that the lists be written as range expressions enclosed in square brackets ('`[a-z]`') and quoted, to prevent the shell from attempting a file name expansion. This is not a feature.

[6] This program was written before `gawk` acquired the ability to split each character in a string into separate array elements.

```
    lf = length(from)
    lt = length(to)
    ltarget = length(target)
    for (i = 1; i <= lt; i++)
        t_ar[substr(from, i, 1)] = substr(to, i, 1)
    if (lt < lf)
        for (; i <= lf; i++)
            t_ar[substr(from, i, 1)] = substr(to, lt, 1)
    for (i = 1; i <= ltarget; i++) {
        c = substr(target, i, 1)
        if (c in t_ar)
            c = t_ar[c]
        result = result c
    }
    return result
}

function translate(from, to)
{
    return $0 = stranslate(from, to, $0)
}

# main program
BEGIN {
    if (ARGC < 3) {
        print "usage: translate from to" > "/dev/stderr"
        exit
    }
    FROM = ARGV[1]
    TO = ARGV[2]
    ARGC = 2
    ARGV[1] = "-"
}

{
    translate(FROM, TO)
    print
}
```

While it is possible to do character transliteration in a user-level function, it is not necessarily efficient, and we (the `gawk` authors) started to consider adding a built-in function. However, shortly after writing this program, we learned that the System V Release 4 `awk` had added the `toupper()` and `tolower()` functions (see Section 9.1.3 [String-Manipulation Functions], page 161). These functions handle the vast majority of the cases where character transliteration is necessary, and so we chose to simply add those functions to `gawk` as well and then leave well enough alone.

An obvious improvement to this program would be to set up the `t_ar` array only once, in a `BEGIN` rule. However, this assumes that the "from" and "to" lists will never change throughout the lifetime of the program.

11.3.4 Printing Mailing Labels

Here is a "real world"[7] program. This script reads lists of names and addresses and generates mailing labels. Each page of labels has 20 labels on it, two across and 10 down. The addresses are guaranteed to be no more than five lines of data. Each address is separated from the next by a blank line.

The basic idea is to read 20 labels worth of data. Each line of each label is stored in the `line` array. The single rule takes care of filling the `line` array and printing the page when 20 labels have been read.

The `BEGIN` rule simply sets `RS` to the empty string, so that `awk` splits records at blank lines (see Section 4.1 [How Input Is Split into Records], page 55). It sets `MAXLINES` to 100, since 100 is the maximum number of lines on the page (20 * 5 = 100).

Most of the work is done in the `printpage()` function. The label lines are stored sequentially in the `line` array. But they have to print horizontally; `line[1]` next to `line[6]`, `line[2]` next to `line[7]`, and so on. Two loops are used to accomplish this. The outer loop, controlled by `i`, steps through every 10 lines of data; this is each row of labels. The inner loop, controlled by `j`, goes through the lines within the row. As `j` goes from 0 to 4, '`i+j`' is the `j`-th line in the row, and '`i+j+5`' is the entry next to it. The output ends up looking something like this:

```
line 1          line 6
line 2          line 7
line 3          line 8
line 4          line 9
line 5          line 10
...
```

The `printf` format string '`%-41s`' left-aligns the data and prints it within a fixed-width field.

As a final note, an extra blank line is printed at lines 21 and 61, to keep the output lined up on the labels. This is dependent on the particular brand of labels in use when the program was written. You will also note that there are two blank lines at the top and two blank lines at the bottom.

The `END` rule arranges to flush the final page of labels; there may not have been an even multiple of 20 labels in the data:

```
# labels.awk --- print mailing labels

# Each label is 5 lines of data that may have blank lines.
# The label sheets have 2 blank lines at the top and 2 at
# the bottom.

BEGIN    { RS = "" ; MAXLINES = 100 }
```

[7] "Real world" is defined as "a program actually used to get something done."

```
function printpage(    i, j)
{
    if (Nlines <= 0)
        return

    printf "\n\n"        # header

    for (i = 1; i <= Nlines; i += 10) {
        if (i == 21 || i == 61)
            print ""
        for (j = 0; j < 5; j++) {
            if (i + j > MAXLINES)
                break
            printf "   %-41s %s\n", line[i+j], line[i+j+5]
        }
        print ""
    }

    printf "\n\n"        # footer

    delete line
}

# main rule
{
    if (Count >= 20) {
        printpage()
        Count = 0
        Nlines = 0
    }
    n = split($0, a, "\n")
    for (i = 1; i <= n; i++)
        line[++Nlines] = a[i]
    for (; i <= 5; i++)
        line[++Nlines] = ""
    Count++
}

END    \
{
    printpage()
}
```

11.3.5 Generating Word-Usage Counts

When working with large amounts of text, it can be interesting to know how often different words appear. For example, an author may overuse certain words, in which case she might wish to find synonyms to substitute for words that appear too often. This subsection develops a program for counting words and presenting the frequency information in a useful format.

At first glance, a program like this would seem to do the job:

```
# Print list of word frequencies

{
    for (i = 1; i <= NF; i++)
        freq[$i]++
}

END {
    for (word in freq)
        printf "%s\t%d\n", word, freq[word]
}
```

The program relies on `awk`'s default field splitting mechanism to break each line up into "words," and uses an associative array named `freq`, indexed by each word, to count the number of times the word occurs. In the `END` rule, it prints the counts.

This program has several problems that prevent it from being useful on real text files:

- The `awk` language considers upper- and lowercase characters to be distinct. Therefore, "bartender" and "Bartender" are not treated as the same word. This is undesirable, since in normal text, words are capitalized if they begin sentences, and a frequency analyzer should not be sensitive to capitalization.
- Words are detected using the `awk` convention that fields are separated just by whitespace. Other characters in the input (except newlines) don't have any special meaning to `awk`. This means that punctuation characters count as part of words.
- The output does not come out in any useful order. You're more likely to be interested in which words occur most frequently or in having an alphabetized table of how frequently each word occurs.

The first problem can be solved by using `tolower()` to remove case distinctions. The second problem can be solved by using `gsub()` to remove punctuation characters. Finally, we solve the third problem by using the system `sort` utility to process the output of the `awk` script. Here is the new version of the program:

```
# wordfreq.awk --- print list of word frequencies

{
    $0 = tolower($0)    # remove case distinctions
    # remove punctuation
    gsub(/[^[:alnum:]_[:blank:]]/, "", $0)
    for (i = 1; i <= NF; i++)
        freq[$i]++
```

```
}

END {
    for (word in freq)
        printf "%s\t%d\n", word, freq[word]
}
```

Assuming we have saved this program in a file named `wordfreq.awk`, and that the data is in `file1`, the following pipeline:

```
awk -f wordfreq.awk file1 | sort -k 2nr
```

produces a table of the words appearing in `file1` in order of decreasing frequency.

The `awk` program suitably massages the data and produces a word frequency table, which is not ordered. The `awk` script's output is then sorted by the `sort` utility and printed on the screen.

The options given to `sort` specify a sort that uses the second field of each input line (skipping one field), that the sort keys should be treated as numeric quantities (otherwise '`15`' would come before '`5`'), and that the sorting should be done in descending (reverse) order.

The `sort` could even be done from within the program, by changing the `END` action to:

```
END {
    sort = "sort -k 2nr"
    for (word in freq)
        printf "%s\t%d\n", word, freq[word] | sort
    close(sort)
}
```

This way of sorting must be used on systems that do not have true pipes at the command-line (or batch-file) level. See the general operating system documentation for more information on how to use the `sort` program.

11.3.6 Removing Duplicates from Unsorted Text

The `uniq` program (see Section 11.2.6 [Printing Nonduplicated Lines of Text], page 245), removes duplicate lines from *sorted* data.

Suppose, however, you need to remove duplicate lines from a data file but that you want to preserve the order the lines are in. A good example of this might be a shell history file. The history file keeps a copy of all the commands you have entered, and it is not unusual to repeat a command several times in a row. Occasionally you might want to compact the history by removing duplicate entries. Yet it is desirable to maintain the order of the original commands.

This simple program does the job. It uses two arrays. The `data` array is indexed by the text of each line. For each line, `data[$0]` is incremented. If a particular line has not been seen before, then `data[$0]` is zero. In this case, the text of the line is stored in `lines[count]`. Each element of `lines` is a unique command, and the indices of `lines` indicate the order in which those lines are encountered. The `END` rule simply prints out the lines, in order:

```
# histsort.awk --- compact a shell history file
```

```
# Thanks to Byron Rakitzis for the general idea

{
    if (data[$0]++ == 0)
        lines[++count] = $0
}

END {
    for (i = 1; i <= count; i++)
        print lines[i]
}
```

This program also provides a foundation for generating other useful information. For example, using the following `print` statement in the `END` rule indicates how often a particular command is used:

```
print data[lines[i]], lines[i]
```

This works because `data[$0]` is incremented each time a line is seen.

11.3.7 Extracting Programs from Texinfo Source Files

Both this chapter and the previous chapter (Chapter 10 [A Library of awk Functions], page 201) present a large number of `awk` programs. If you want to experiment with these programs, it is tedious to have to type them in by hand. Here we present a program that can extract parts of a Texinfo input file into separate files.

This book is written in Texinfo (`http://www.gnu.org/software/texinfo/`), the GNU project's document formatting language. A single Texinfo source file can be used to produce both printed and online documentation. Texinfo is fully documented in the book *Texinfo—The GNU Documentation Format*, available from the Free Software Foundation.

For our purposes, it is enough to know three things about Texinfo input files:

- The "at" symbol ('`@`') is special in Texinfo, much as the backslash ('\') is in C or `awk`. Literal '`@`' symbols are represented in Texinfo source files as '`@@`'.
- Comments start with either '`@c`' or '`@comment`'. The file-extraction program works by using special comments that start at the beginning of a line.
- Lines containing '`@group`' and '`@end group`' commands bracket example text that should not be split across a page boundary. (Unfortunately, TeX isn't always smart enough to do things exactly right, so we have to give it some help.)

The following program, `extract.awk`, reads through a Texinfo source file and does two things, based on the special comments. Upon seeing '`@c system ...`', it runs a command, by extracting the command text from the control line and passing it on to the `system()` function (see Section 9.1.4 [Input/Output Functions], page 173). Upon seeing '`@c file` *`filename`*', each subsequent line is sent to the file *filename*, until '`@c endfile`' is encountered. The rules in `extract.awk` match either '`@c`' or '`@comment`' by letting the '`omment`' part be optional. Lines containing '`@group`' and '`@end group`' are simply removed. `extract.awk` uses the `join()` library function (see Section 10.2.6 [Merging an Array into a String], page 209).

The example programs in the online Texinfo source for *GAWK: Effective AWK Programming* (`gawktexi.in`) have all been bracketed inside '`file`' and '`endfile`' lines. The gawk distribution uses a copy of extract.awk to extract the sample programs and install many of them in a standard directory where gawk can find them. The Texinfo file looks something like this:

```
...
This program has a @code{BEGIN} rule,
that prints a nice message:

@example
@c file examples/messages.awk
BEGIN @{ print "Don't panic!" @}
@c end file
@end example

It also prints some final advice:

@example
@c file examples/messages.awk
END @{ print "Always avoid bored archeologists!" @}
@c end file
@end example
...
```

extract.awk begins by setting IGNORECASE to one, so that mixed upper- and lowercase letters in the directives won't matter.

The first rule handles calling system(), checking that a command is given (NF is at least three) and also checking that the command exits with a zero exit status, signifying OK:

```
# extract.awk --- extract files and run programs
#                 from texinfo files

BEGIN    { IGNORECASE = 1 }

/^@c(omment)?[ \t]+system/    \
{
    if (NF < 3) {
        e = (FILENAME ":" FNR)
        e = (e  ": badly formed `system' line")
        print e > "/dev/stderr"
        next
    }
    $1 = ""
    $2 = ""
    stat = system($0)
    if (stat != 0) {
        e = (FILENAME ":" FNR)
        e = (e ": warning: system returned " stat)
        print e > "/dev/stderr"
    }
```

```
}
```

The variable `e` is used so that the rule fits nicely on the page.

The second rule handles moving data into files. It verifies that a file name is given in the directive. If the file named is not the current file, then the current file is closed. Keeping the current file open until a new file is encountered allows the use of the '>' redirection for printing the contents, keeping open file management simple.

The `for` loop does the work. It reads lines using `getline` (see Section 4.9 [Explicit Input with `getline`], page 73). For an unexpected end of file, it calls the `unexpected_eof()` function. If the line is an "endfile" line, then it breaks out of the loop. If the line is an '`@group`' or '`@end group`' line, then it ignores it and goes on to the next line. Similarly, comments within examples are also ignored.

Most of the work is in the following few lines. If the line has no '`@`' symbols, the program can print it directly. Otherwise, each leading '`@`' must be stripped off. To remove the '`@`' symbols, the line is split into separate elements of the array `a`, using the `split()` function (see Section 9.1.3 [String-Manipulation Functions], page 161). The '`@`' symbol is used as the separator character. Each element of `a` that is empty indicates two successive '`@`' symbols in the original line. For each two empty elements ('`@@`' in the original file), we have to add a single '`@`' symbol back in.[8]

When the processing of the array is finished, `join()` is called with the value of `SUBSEP`, to rejoin the pieces back into a single line. That line is then printed to the output file:

```
/^@c(omment)?[ \t]+file/    \
{
    if (NF != 3) {
        e = (FILENAME ":" FNR ": badly formed ‘file’ line")
        print e > "/dev/stderr"
        next
    }
    if ($3 != curfile) {
        if (curfile != "")
            close(curfile)
        curfile = $3
    }

    for (;;) {
        if ((getline line) <= 0)
            unexpected_eof()
        if (line ~ /^@c(omment)?[ \t]+endfile/)
            break
        else if (line ~ /^@(end[ \t]+)?group/)
            continue
        else if (line ~ /^@c(omment+)?[ \t]+/)
            continue
        if (index(line, "@") == 0) {
```

[8] This program was written before `gawk` had the `gensub()` function. Consider how you might use it to simplify the code.

```
                print line > curfile
                continue
            }
            n = split(line, a, "@")
            # if a[1] == "", means leading @,
            # don't add one back in.
            for (i = 2; i <= n; i++) {
                if (a[i] == "") { # was an @@
                    a[i] = "@"
                    if (a[i+1] == "")
                        i++
                }
            }
            print join(a, 1, n, SUBSEP) > curfile
        }
    }
```

An important thing to note is the use of the '>' redirection. Output done with '>' only opens the file once; it stays open and subsequent output is appended to the file (see Section 5.6 [Redirecting Output of print and printf], page 89). This makes it easy to mix program text and explanatory prose for the same sample source file (as has been done here!) without any hassle. The file is only closed when a new data file name is encountered or at the end of the input file.

Finally, the function unexpected_eof() prints an appropriate error message and then exits. The END rule handles the final cleanup, closing the open file:

```
function unexpected_eof()
{
    printf("%s:%d: unexpected EOF or error\n",
        FILENAME, FNR) > "/dev/stderr"
    exit 1
}

END {
    if (curfile)
        close(curfile)
}
```

11.3.8 A Simple Stream Editor

The sed utility is a stream editor, a program that reads a stream of data, makes changes to it, and passes it on. It is often used to make global changes to a large file or to a stream of data generated by a pipeline of commands. While sed is a complicated program in its own right, its most common use is to perform global substitutions in the middle of a pipeline:

```
command1 < orig.data | sed 's/old/new/g' | command2 > result
```

Here, 's/old/new/g' tells sed to look for the regexp 'old' on each input line and globally replace it with the text 'new', i.e., all the occurrences on a line. This is similar to awk's gsub() function (see Section 9.1.3 [String-Manipulation Functions], page 161).

The following program, `awksed.awk`, accepts at least two command-line arguments: the pattern to look for and the text to replace it with. Any additional arguments are treated as data file names to process. If none are provided, the standard input is used:

```
# awksed.awk --- do s/foo/bar/g using just print
#    Thanks to Michael Brennan for the idea

function usage()
{
    print "usage: awksed pat repl [files...]" > "/dev/stderr"
    exit 1
}

BEGIN {
    # validate arguments
    if (ARGC < 3)
        usage()

    RS = ARGV[1]
    ORS = ARGV[2]

    # don't use arguments as files
    ARGV[1] = ARGV[2] = ""
}

# look ma, no hands!
{
    if (RT == "")
        printf "%s", $0
    else
        print
}
```

The program relies on `gawk`'s ability to have `RS` be a regexp, as well as on the setting of `RT` to the actual text that terminates the record (see Section 4.1 [How Input Is Split into Records], page 55).

The idea is to have `RS` be the pattern to look for. `gawk` automatically sets `$0` to the text between matches of the pattern. This is text that we want to keep, unmodified. Then, by setting `ORS` to the replacement text, a simple `print` statement outputs the text we want to keep, followed by the replacement text.

There is one wrinkle to this scheme, which is what to do if the last record doesn't end with text that matches `RS`. Using a `print` statement unconditionally prints the replacement text, which is not correct. However, if the file did not end in text that matches `RS`, `RT` is set to the null string. In this case, we can print `$0` using `printf` (see Section 5.5 [Using `printf` Statements for Fancier Printing], page 84).

The `BEGIN` rule handles the setup, checking for the right number of arguments and calling `usage()` if there is a problem. Then it sets `RS` and `ORS` from the command-line arguments and sets `ARGV[1]` and `ARGV[2]` to the null string, so that they are not treated as file names (see Section 7.5.3 [Using `ARGC` and `ARGV`], page 143).

The `usage()` function prints an error message and exits. Finally, the single rule handles the printing scheme outlined above, using `print` or `printf` as appropriate, depending upon the value of `RT`.

11.3.9 An Easy Way to Use Library Functions

In Section 2.7 [Including Other Files Into Your Program], page 39, we saw how `gawk` provides a built-in file-inclusion capability. However, this is a `gawk` extension. This section provides the motivation for making file inclusion available for standard `awk`, and shows how to do it using a combination of shell and `awk` programming.

Using library functions in `awk` can be very beneficial. It encourages code reuse and the writing of general functions. Programs are smaller and therefore clearer. However, using library functions is only easy when writing `awk` programs; it is painful when running them, requiring multiple `-f` options. If `gawk` is unavailable, then so too is the `AWKPATH` environment variable and the ability to put `awk` functions into a library directory (see Section 2.2 [Command-Line Options], page 29). It would be nice to be able to write programs in the following manner:

```
# library functions
@include getopt.awk
@include join.awk
...

# main program
BEGIN {
    while ((c = getopt(ARGC, ARGV, "a:b:cde")) != -1)
        ...
    ...
}
```

The following program, `igawk.sh`, provides this service. It simulates `gawk`'s searching of the `AWKPATH` variable and also allows *nested* includes; i.e., a file that is included with '`@include`' can contain further '`@include`' statements. `igawk` makes an effort to only include files once, so that nested includes don't accidentally include a library function twice.

`igawk` should behave just like `gawk` externally. This means it should accept all of `gawk`'s command-line arguments, including the ability to have multiple source files specified via `-f`, and the ability to mix command-line and library source files.

The program is written using the POSIX Shell (`sh`) command language.[9] It works as follows:

1. Loop through the arguments, saving anything that doesn't represent `awk` source code for later, when the expanded program is run.
2. For any arguments that do represent `awk` text, put the arguments into a shell variable that will be expanded. There are two cases:

---

[9] Fully explaining the `sh` language is beyond the scope of this book. We provide some minimal explanations, but see a good shell programming book if you wish to understand things in more depth.

   a. Literal text, provided with `--source` or `--source=`. This text is just appended directly.
   b. Source file names, provided with `-f`. We use a neat trick and append '`@include` *`filename`*' to the shell variable's contents. Since the file-inclusion program works the way `gawk` does, this gets the text of the file included into the program at the correct point.
3. Run an `awk` program (naturally) over the shell variable's contents to expand '`@include`' statements. The expanded program is placed in a second shell variable.
4. Run the expanded program with `gawk` and any other original command-line arguments that the user supplied (such as the data file names).

This program uses shell variables extensively: for storing command-line arguments, the text of the `awk` program that will expand the user's program, for the user's original program, and for the expanded program. Doing so removes some potential problems that might arise were we to use temporary files instead, at the cost of making the script somewhat more complicated.

The initial part of the program turns on shell tracing if the first argument is '`debug`'.

The next part loops through all the command-line arguments. There are several cases of interest:

`--` This ends the arguments to `igawk`. Anything else should be passed on to the user's `awk` program without being evaluated.

`-W` This indicates that the next option is specific to `gawk`. To make argument processing easier, the `-W` is appended to the front of the remaining arguments and the loop continues. (This is an `sh` programming trick. Don't worry about it if you are not familiar with `sh`.)

`-v`, `-F` These are saved and passed on to `gawk`.

`-f`, `--file`, `--file=`, `-Wfile=`
: The file name is appended to the shell variable `program` with an '`@include`' statement. The `expr` utility is used to remove the leading option part of the argument (e.g., '`--file=`'). (Typical `sh` usage would be to use the `echo` and `sed` utilities to do this work. Unfortunately, some versions of `echo` evaluate escape sequences in their arguments, possibly mangling the program text. Using `expr` avoids this problem.)

`--source`, `--source=`, `-Wsource=`
: The source text is appended to `program`.

`--version`, `-Wversion`
: `igawk` prints its version number, runs '`gawk --version`' to get the `gawk` version information, and then exits.

If none of the `-f`, `--file`, `-Wfile`, `--source`, or `-Wsource` arguments are supplied, then the first nonoption argument should be the `awk` program. If there are no command-line arguments left, `igawk` prints an error message and exits. Otherwise, the first argument is appended to `program`. In any case, after the arguments have been processed, `program` contains the complete text of the original `awk` program.

The program is as follows:

```
#! /bin/sh
# igawk --- like gawk but do @include processing

if [ "$1" = debug ]
then
    set -x
    shift
fi

# A literal newline, so that program text is formatted correctly
n='
'

# Initialize variables to empty
program=
opts=

while [ $# -ne 0 ] # loop over arguments
do
    case $1 in
    --)     shift
            break ;;

    -W)     shift
            # The ${x?'message here'} construct prints a
            # diagnostic if $x is the null string
            set -- -W"${@?'missing operand'}"
            continue ;;

    -[vF])  opts="$opts $1 '${2?'missing operand'}'"
            shift ;;

    -[vF]*) opts="$opts '$1'" ;;

    -f)     program="$program$n@include ${2?'missing operand'}"
            shift ;;

    -f*)    f=$(expr "$1" : '-f\(.*\)')
            program="$program$n@include $f" ;;

    -[W-]file=*)
            f=$(expr "$1" : '-.file=\(.*\)')
            program="$program$n@include $f" ;;

    -[W-]file)
            program="$program$n@include ${2?'missing operand'}"
            shift ;;
```

```
    -[W-]source=*)
            t=$(expr "$1" : '-.source=\(.*\)')
            program="$program$n$t" ;;

    -[W-]source)
            program="$program$n${2?'missing operand'}"
            shift ;;

    -[W-]version)
            echo igawk: version 3.0 1>&2
            gawk --version
            exit 0 ;;

    -[W-]*) opts="$opts '$1'" ;;

    *)      break ;;
    esac
    shift
done

if [ -z "$program" ]
then
     program=${1?'missing program'}
     shift
fi

# At this point, 'program' has the program.
```

The awk program to process '@include' directives is stored in the shell variable expand_prog. Doing this keeps the shell script readable. The awk program reads through the user's program, one line at a time, using getline (see Section 4.9 [Explicit Input with getline], page 73). The input file names and '@include' statements are managed using a stack. As each '@include' is encountered, the current file name is "pushed" onto the stack and the file named in the '@include' directive becomes the current file name. As each file is finished, the stack is "popped," and the previous input file becomes the current input file again. The process is started by making the original file the first one on the stack.

The pathto() function does the work of finding the full path to a file. It simulates gawk's behavior when searching the AWKPATH environment variable (see Section 2.5.1 [The AWKPATH Environment Variable], page 36). If a file name has a '/' in it, no path search is done. Similarly, if the file name is "-", then that string is used as-is. Otherwise, the file name is concatenated with the name of each directory in the path, and an attempt is made to open the generated file name. The only way to test if a file can be read in awk is to go ahead and try to read it with getline; this is what pathto() does.[10] If the file can be read, it is closed and the file name is returned:

[10] On some very old versions of awk, the test 'getline junk < t' can loop forever if the file exists but is empty. Caveat emptor.

```
expand_prog='

function pathto(file,    i, t, junk)
{
    if (index(file, "/") != 0)
        return file

    if (file == "-")
        return file

    for (i = 1; i <= ndirs; i++) {
        t = (pathlist[i] "/" file)
        if ((getline junk < t) > 0) {
            # found it
            close(t)
            return t
        }
    }
    return ""
}
```

The main program is contained inside one `BEGIN` rule. The first thing it does is set up the `pathlist` array that `pathto()` uses. After splitting the path on ':', null elements are replaced with `"."`, which represents the current directory:

```
BEGIN {
    path = ENVIRON["AWKPATH"]
    ndirs = split(path, pathlist, ":")
    for (i = 1; i <= ndirs; i++) {
        if (pathlist[i] == "")
            pathlist[i] = "."
    }
```

The stack is initialized with `ARGV[1]`, which will be `/dev/stdin`. The main loop comes next. Input lines are read in succession. Lines that do not start with '`@include`' are printed verbatim. If the line does start with '`@include`', the file name is in `$2`. `pathto()` is called to generate the full path. If it cannot, then the program prints an error message and continues.

The next thing to check is if the file is included already. The `processed` array is indexed by the full file name of each included file and it tracks this information for us. If the file is seen again, a warning message is printed. Otherwise, the new file name is pushed onto the stack and processing continues.

Finally, when `getline` encounters the end of the input file, the file is closed and the stack is popped. When `stackptr` is less than zero, the program is done:

```
    stackptr = 0
    input[stackptr] = ARGV[1] # ARGV[1] is first file

    for (; stackptr >= 0; stackptr--) {
        while ((getline < input[stackptr]) > 0) {
```

```
            if (tolower($1) != "@include") {
                print
                continue
            }
            fpath = pathto($2)
            if (fpath == "") {
                printf("igawk:%s:%d: cannot find %s\n",
                    input[stackptr], FNR, $2) > "/dev/stderr"
                continue
            }
            if (! (fpath in processed)) {
                processed[fpath] = input[stackptr]
                input[++stackptr] = fpath  # push onto stack
            } else
                print $2, "included in", input[stackptr],
                    "already included in",
                    processed[fpath] > "/dev/stderr"
        }
        close(input[stackptr])
    }
}'  # close quote ends 'expand_prog' variable

processed_program=$(gawk -- "$expand_prog" /dev/stdin << EOF
$program
EOF
)
```

The shell construct '*command* << *marker*' is called a *here document*. Everything in the shell script up to the *marker* is fed to *command* as input. The shell processes the contents of the here document for variable and command substitution (and possibly other things as well, depending upon the shell).

The shell construct '`$(...)`' is called *command substitution*. The output of the command inside the parentheses is substituted into the command line. Because the result is used in a variable assignment, it is saved as a single string, even if the results contain whitespace.

The expanded program is saved in the variable `processed_program`. It's done in these steps:

1. Run `gawk` with the '`@include`'-processing program (the value of the `expand_prog` shell variable) on standard input.
2. Standard input is the contents of the user's program, from the shell variable `program`. Its contents are fed to `gawk` via a here document.
3. The results of this processing are saved in the shell variable `processed_program` by using command substitution.

The last step is to call `gawk` with the expanded program, along with the original options and command-line arguments that the user supplied.

```
eval gawk $opts -- '"$processed_program"' '"$@"'
```

The `eval` command is a shell construct that reruns the shell's parsing process. This keeps things properly quoted.

This version of `igawk` represents my fifth version of this program. There are four key simplifications that make the program work better:

- Using '`@include`' even for the files named with `-f` makes building the initial collected `awk` program much simpler; all the '`@include`' processing can be done once.
- Not trying to save the line read with `getline` in the `pathto()` function when testing for the file's accessibility for use with the main program simplifies things considerably.
- Using a `getline` loop in the `BEGIN` rule does it all in one place. It is not necessary to call out to a separate loop for processing nested '`@include`' statements.
- Instead of saving the expanded program in a temporary file, putting it in a shell variable avoids some potential security problems. This has the disadvantage that the script relies upon more features of the `sh` language, making it harder to follow for those who aren't familiar with `sh`.

Also, this program illustrates that it is often worthwhile to combine `sh` and `awk` programming together. You can usually accomplish quite a lot, without having to resort to low-level programming in C or C++, and it is frequently easier to do certain kinds of string and argument manipulation using the shell than it is in `awk`.

Finally, `igawk` shows that it is not always necessary to add new features to a program; they can often be layered on top.

As an additional example of this, consider the idea of having two files in a directory in the search path:

`default.awk`
: This file contains a set of default library functions, such as `getopt()` and `assert()`.

`site.awk`
: This file contains library functions that are specific to a site or installation; i.e., locally developed functions. Having a separate file allows `default.awk` to change with new `gawk` releases, without requiring the system administrator to update it each time by adding the local functions.

One user suggested that `gawk` be modified to automatically read these files upon startup. Instead, it would be very simple to modify `igawk` to do this. Since `igawk` can process nested '`@include`' directives, `default.awk` could simply contain '`@include`' statements for the desired library functions.

11.3.10 Finding Anagrams From A Dictionary

An interesting programming challenge is to search for *anagrams* in a word list (such as `/usr/share/dict/words` on many GNU/Linux systems). One word is an anagram of another if both words contain the same letters (for example, "babbling" and "blabbing").

An elegant algorithm is presented in Column 2, Problem C of Jon Bentley's *Programming Pearls*, second edition. The idea is to give words that are anagrams a common signature, sort all the words together by their signature, and then print them. Dr. Bentley observes that taking the letters in each word and sorting them produces that common signature.

The following program uses arrays of arrays to bring together words with the same signature and array sorting to print the words in sorted order.

```
# anagram.awk --- An implementation of the anagram finding algorithm
#                 from Jon Bentley's "Programming Pearls", 2nd edition.
#                 Addison Wesley, 2000, ISBN 0-201-65788-0.
#                 Column 2, Problem C, section 2.8, pp 18-20.

/'s$/   { next }        # Skip possessives
```

The program starts with a header, and then a rule to skip possessives in the dictionary file. The next rule builds up the data structure. The first dimension of the array is indexed by the signature; the second dimension is the word itself:

```
{
    key = word2key($1)  # Build signature
    data[key][$1] = $1  # Store word with signature
}
```

The `word2key()` function creates the signature. It splits the word apart into individual letters, sorts the letters, and then joins them back together:

```
# word2key --- split word apart into letters, sort, joining back together

function word2key(word,     a, i, n, result)
{
    n = split(word, a, "")
    asort(a)

    for (i = 1; i <= n; i++)
        result = result a[i]

    return result
}
```

Finally, the `END` rule traverses the array and prints out the anagram lists. It sends the output to the system `sort` command, since otherwise the anagrams would appear in arbitrary order:

```
END {
    sort = "sort"
    for (key in data) {
        # Sort words with same key
        nwords = asorti(data[key], words)
        if (nwords == 1)
            continue

        # And print. Minor glitch: trailing space at end of each line
        for (j = 1; j <= nwords; j++)
            printf("%s ", words[j]) | sort
        print "" | sort
    }
    close(sort)
}
```

Here is some partial output when the program is run:

```
$ gawk -f anagram.awk /usr/share/dict/words | grep '^b'
...
babbled blabbed
babbler blabber brabble
babblers blabbers brabbles
babbling blabbing
babbly blabby
babel bable
babels beslab
babery yabber
...
```

11.3.11 And Now For Something Completely Different

The following program was written by Davide Brini and is published on his website (`http://backreference.org/2011/02/03/obfuscated-awk/`). It serves as his signature in the Usenet group `comp.lang.awk`. He supplies the following copyright terms:

> Copyright © 2008 Davide Brini
>
> Copying and distribution of the code published in this page, with or without modification, are permitted in any medium without royalty provided the copyright notice and this notice are preserved.

Here is the program:

```
awk 'BEGIN{O="~"~"~";o="=="=="==";o+=+o;x=O""O;while(X++<=x+o+o)c=c"%c";
printf c,(x-O)*(x-O),x*(x-o)-o,x*(x-O)+x-O-o,+x*(x-O)-x+o,X*(o*o+O)+x-O,
X*(X-x)-o*o,(x+X)*o*o+o,x*(X-x)-O-O,x-O+(O+o+X+x)*(o+O),X*X-X*(x-O)-x+O,
O+X*(o*(o+O)+O),+x+O+X*o,x*(x-o),(o+X+x)*o*o-(x-O-O),O+(X-x)*(X+O),x-O}'
```

We leave it to you to determine what the program does.

Part III:
Moving Beyond Standard awk With gawk

12 Advanced Features of gawk

Write documentation as if whoever reads it is a violent psychopath who knows where you live.
Steve English, as quoted by Peter Langston

This chapter discusses advanced features in gawk. It's a bit of a "grab bag" of items that are otherwise unrelated to each other. First, a command-line option allows gawk to recognize nondecimal numbers in input data, not just in awk programs. Then, gawk's special features for sorting arrays are presented. Next, two-way I/O, discussed briefly in earlier parts of this book, is described in full detail, along with the basics of TCP/IP networking. Finally, gawk can *profile* an awk program, making it possible to tune it for performance.

A number of advanced features require separate chapters of their own:

- Chapter 13 [Internationalization with gawk], page 291, discusses how to internationalize your awk programs, so that they can speak multiple national languages.
- Chapter 14 [Debugging awk Programs], page 301, describes gawk's built-in command-line debugger for debugging awk programs.
- Chapter 15 [Arithmetic and Arbitrary Precision Arithmetic with gawk], page 317, describes how you can use gawk to perform arbitrary-precision arithmetic.
- Chapter 16 [Writing Extensions for gawk], page 333, discusses the ability to dynamically add new built-in functions to gawk.

12.1 Allowing Nondecimal Input Data

If you run gawk with the --non-decimal-data option, you can have nondecimal constants in your input data:

```
$ echo 0123 123 0x123 |
> gawk --non-decimal-data '{ printf "%d, %d, %d\n",
>                                         $1, $2, $3 }'
⊣ 83, 123, 291
```

For this feature to work, write your program so that gawk treats your data as numeric:

```
$ echo 0123 123 0x123 | gawk '{ print $1, $2, $3 }'
⊣ 0123 123 0x123
```

The print statement treats its expressions as strings. Although the fields can act as numbers when necessary, they are still strings, so print does not try to treat them numerically. You may need to add zero to a field to force it to be treated as a number. For example:

```
$ echo 0123 123 0x123 | gawk --non-decimal-data '
> { print $1, $2, $3
>   print $1 + 0, $2 + 0, $3 + 0 }'
⊣ 0123 123 0x123
⊣ 83 123 291
```

Because it is common to have decimal data with leading zeros, and because using this facility could lead to surprising results, the default is to leave it disabled. If you want it, you must explicitly request it.

> **CAUTION:** *Use of this option is not recommended.* It can break old programs very badly. Instead, use the strtonum() function to convert your data (see

Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97). This makes your programs easier to write and easier to read, and leads to less surprising results.

12.2 Controlling Array Traversal and Array Sorting

gawk lets you control the order in which a 'for (i in array)' loop traverses an array.

In addition, two built-in functions, asort() and asorti(), let you sort arrays based on the array values and indices, respectively. These two functions also provide control over the sorting criteria used to order the elements during sorting.

12.2.1 Controlling Array Traversal

By default, the order in which a 'for (i in array)' loop scans an array is not defined; it is generally based upon the internal implementation of arrays inside awk.

Often, though, it is desirable to be able to loop over the elements in a particular order that you, the programmer, choose. gawk lets you do this.

Section 8.1.6 [Using Predefined Array Scanning Orders], page 149, describes how you can assign special, pre-defined values to PROCINFO["sorted_in"] in order to control the order in which gawk will traverse an array during a for loop.

In addition, the value of PROCINFO["sorted_in"] can be a function name. This lets you traverse an array based on any custom criterion. The array elements are ordered according to the return value of this function. The comparison function should be defined with at least four arguments:

```
function comp_func(i1, v1, i2, v2)
{
    compare elements 1 and 2 in some fashion
    return < 0; 0; or > 0
}
```

Here, *i1* and *i2* are the indices, and *v1* and *v2* are the corresponding values of the two elements being compared. Either *v1* or *v2*, or both, can be arrays if the array being traversed contains subarrays as values. (See Section 8.6 [Arrays of Arrays], page 156, for more information about subarrays.) The three possible return values are interpreted as follows:

comp_func(i1, v1, i2, v2) < 0
: Index *i1* comes before index *i2* during loop traversal.

comp_func(i1, v1, i2, v2) == 0
: Indices *i1* and *i2* come together but the relative order with respect to each other is undefined.

comp_func(i1, v1, i2, v2) > 0
: Index *i1* comes after index *i2* during loop traversal.

Our first comparison function can be used to scan an array in numerical order of the indices:

```
function cmp_num_idx(i1, v1, i2, v2)
{
     # numerical index comparison, ascending order
```

```
        return (i1 - i2)
}
```

Our second function traverses an array based on the string order of the element values rather than by indices:

```
function cmp_str_val(i1, v1, i2, v2)
{
    # string value comparison, ascending order
    v1 = v1 ""
    v2 = v2 ""
    if (v1 < v2)
        return -1
    return (v1 != v2)
}
```

The third comparison function makes all numbers, and numeric strings without any leading or trailing spaces, come out first during loop traversal:

```
function cmp_num_str_val(i1, v1, i2, v2,   n1, n2)
{
     # numbers before string value comparison, ascending order
     n1 = v1 + 0
     n2 = v2 + 0
     if (n1 == v1)
         return (n2 == v2) ? (n1 - n2) : -1
     else if (n2 == v2)
         return 1
     return (v1 < v2) ? -1 : (v1 != v2)
}
```

Here is a main program to demonstrate how gawk behaves using each of the previous functions:

```
BEGIN {
    data["one"] = 10
    data["two"] = 20
    data[10] = "one"
    data[100] = 100
    data[20] = "two"

    f[1] = "cmp_num_idx"
    f[2] = "cmp_str_val"
    f[3] = "cmp_num_str_val"
    for (i = 1; i <= 3; i++) {
        printf("Sort function: %s\n", f[i])
        PROCINFO["sorted_in"] = f[i]
        for (j in data)
            printf("\tdata[%s] = %s\n", j, data[j])
        print ""
    }
```

```
}
```

Here are the results when the program is run:

```
$ gawk -f compdemo.awk
⊣ Sort function: cmp_num_idx      Sort by numeric index
⊣     data[two] = 20
⊣     data[one] = 10              Both strings are numerically zero
⊣     data[10] = one
⊣     data[20] = two
⊣     data[100] = 100
⊣
⊣ Sort function: cmp_str_val      Sort by element values as strings
⊣     data[one] = 10
⊣     data[100] = 100             String 100 is less than string 20
⊣     data[two] = 20
⊣     data[10] = one
⊣     data[20] = two
⊣
⊣ Sort function: cmp_num_str_val  Sort all numeric values before all strings
⊣     data[one] = 10
⊣     data[two] = 20
⊣     data[100] = 100
⊣     data[10] = one
⊣     data[20] = two
```

Consider sorting the entries of a GNU/Linux system password file according to login name. The following program sorts records by a specific field position and can be used for this purpose:

```
# sort.awk --- simple program to sort by field position
# field position is specified by the global variable POS

function cmp_field(i1, v1, i2, v2)
{
    # comparison by value, as string, and ascending order
    return v1[POS] < v2[POS] ? -1 : (v1[POS] != v2[POS])
}

{
    for (i = 1; i <= NF; i++)
        a[NR][i] = $i
}

END {
    PROCINFO["sorted_in"] = "cmp_field"
    if (POS < 1 || POS > NF)
        POS = 1
    for (i in a) {
        for (j = 1; j <= NF; j++)
```

```
            printf("%s%c", a[i][j], j < NF ? ":" : "")
        print ""
    }
}
```

The first field in each entry of the password file is the user's login name, and the fields are separated by colons. Each record defines a subarray, with each field as an element in the subarray. Running the program produces the following output:

```
$ gawk -v POS=1 -F: -f sort.awk /etc/passwd
⊣ adm:x:3:4:adm:/var/adm:/sbin/nologin
⊣ apache:x:48:48:Apache:/var/www:/sbin/nologin
⊣ avahi:x:70:70:Avahi daemon:/:/sbin/nologin
...
```

The comparison should normally always return the same value when given a specific pair of array elements as its arguments. If inconsistent results are returned then the order is undefined. This behavior can be exploited to introduce random order into otherwise seemingly ordered data:

```
function cmp_randomize(i1, v1, i2, v2)
{
    # random order
    return (2 - 4 * rand())
}
```

As mentioned above, the order of the indices is arbitrary if two elements compare equal. This is usually not a problem, but letting the tied elements come out in arbitrary order can be an issue, especially when comparing item values. The partial ordering of the equal elements may change during the next loop traversal, if other elements are added or removed from the array. One way to resolve ties when comparing elements with otherwise equal values is to include the indices in the comparison rules. Note that doing this may make the loop traversal less efficient, so consider it only if necessary. The following comparison functions force a deterministic order, and are based on the fact that the indices of two elements are never equal:

```
function cmp_numeric(i1, v1, i2, v2)
{
    # numerical value (and index) comparison, descending order
    return (v1 != v2) ? (v2 - v1) : (i2 - i1)
}

function cmp_string(i1, v1, i2, v2)
{
    # string value (and index) comparison, descending order
    v1 = v1 i1
    v2 = v2 i2
    return (v1 > v2) ? -1 : (v1 != v2)
}
```

A custom comparison function can often simplify ordered loop traversal, and the sky is really the limit when it comes to designing such a function.

When string comparisons are made during a sort, either for element values where one or both aren't numbers, or for element indices handled as strings, the value of IGNORECASE (see Section 7.5 [Built-in Variables], page 134) controls whether the comparisons treat corresponding uppercase and lowercase letters as equivalent or distinct.

Another point to keep in mind is that in the case of subarrays the element values can themselves be arrays; a production comparison function should use the isarray() function (see Section 9.1.7 [Getting Type Information], page 183), to check for this, and choose a defined sorting order for subarrays.

All sorting based on PROCINFO["sorted_in"] is disabled in POSIX mode, since the PROCINFO array is not special in that case.

As a side note, sorting the array indices before traversing the array has been reported to add 15% to 20% overhead to the execution time of awk programs. For this reason, sorted array traversal is not the default.

12.2.2 Sorting Array Values and Indices with gawk

In most awk implementations, sorting an array requires writing a sort() function. While this can be educational for exploring different sorting algorithms, usually that's not the point of the program. gawk provides the built-in asort() and asorti() functions (see Section 9.1.3 [String-Manipulation Functions], page 161) for sorting arrays. For example:

```
populate the array data
n = asort(data)
for (i = 1; i <= n; i++)
    do something with data[i]
```

After the call to asort(), the array data is indexed from 1 to some number *n*, the total number of elements in data. (This count is asort()'s return value.) data[1] ≤ data[2] ≤ data[3], and so on. The comparison is based on the type of the elements (see Section 6.3.2 [Variable Typing and Comparison Expressions], page 110). All numeric values come before all string values, which in turn come before all subarrays.

An important side effect of calling asort() is that *the array's original indices are irrevocably lost.* As this isn't always desirable, asort() accepts a second argument:

```
populate the array source
n = asort(source, dest)
for (i = 1; i <= n; i++)
    do something with dest[i]
```

In this case, gawk copies the source array into the dest array and then sorts dest, destroying its indices. However, the source array is not affected.

asort() accepts a third string argument to control comparison of array elements. As with PROCINFO["sorted_in"], this argument may be one of the predefined names that gawk provides (see Section 8.1.6 [Using Predefined Array Scanning Orders], page 149), or the name of a user-defined function (see Section 12.2.1 [Controlling Array Traversal], page 278).

> **NOTE:** In all cases, the sorted element values consist of the original array's element values. The ability to control comparison merely affects the way in which they are sorted.

Often, what's needed is to sort on the values of the *indices* instead of the values of the elements. To do that, use the `asorti()` function. The interface is identical to that of `asort()`, except that the index values are used for sorting, and become the values of the result array:

```
{ source[$0] = some_func($0) }

END {
    n = asorti(source, dest)
    for (i = 1; i <= n; i++) {
        Work with sorted indices directly:
        do something with dest[i]
        ...
        Access original array via sorted indices:
        do something with source[dest[i]]
    }
}
```

Similar to `asort()`, in all cases, the sorted element values consist of the original array's indices. The ability to control comparison merely affects the way in which they are sorted.

Sorting the array by replacing the indices provides maximal flexibility. To traverse the elements in decreasing order, use a loop that goes from *n* down to 1, either over the elements or over the indices.[1]

Copying array indices and elements isn't expensive in terms of memory. Internally, `gawk` maintains *reference counts* to data. For example, when `asort()` copies the first array to the second one, there is only one copy of the original array elements' data, even though both arrays use the values.

Because `IGNORECASE` affects string comparisons, the value of `IGNORECASE` also affects sorting for both `asort()` and `asorti()`. Note also that the locale's sorting order does *not* come into play; comparisons are based on character values only.[2] Caveat Emptor.

12.3 Two-Way Communications with Another Process

```
From: brennan@whidbey.com (Mike Brennan)
Newsgroups: comp.lang.awk
Subject: Re: Learn the SECRET to Attract Women Easily
Date: 4 Aug 1997 17:34:46 GMT
Message-ID: <5s53rm$eca@news.whidbey.com>

On 3 Aug 1997 13:17:43 GMT, Want More Dates???
<tracy78@kilgrona.com> wrote:
>Learn the SECRET to Attract Women Easily
>
>The SCENT(tm)  Pheromone Sex Attractant For Men to Attract Women

The scent of awk programmers is a lot more attractive to women than
the scent of perl programmers.
--
```

[1] You may also use one of the predefined sorting names that sorts in decreasing order.

[2] This is true because locale-based comparison occurs only when in POSIX compatibility mode, and since `asort()` and `asorti()` are `gawk` extensions, they are not available in that case.

```
Mike Brennan
```

It is often useful to be able to send data to a separate program for processing and then read the result. This can always be done with temporary files:

```
# Write the data for processing
tempfile = ("mydata." PROCINFO["pid"])
while (not done with data)
    print data | ("subprogram > " tempfile)
close("subprogram > " tempfile)

# Read the results, remove tempfile when done
while ((getline newdata < tempfile) > 0)
    process newdata appropriately
close(tempfile)
system("rm " tempfile)
```

This works, but not elegantly. Among other things, it requires that the program be run in a directory that cannot be shared among users; for example, `/tmp` will not do, as another user might happen to be using a temporary file with the same name.

However, with `gawk`, it is possible to open a *two-way* pipe to another process. The second process is termed a *coprocess*, since it runs in parallel with `gawk`. The two-way connection is created using the '`|&`' operator (borrowed from the Korn shell, `ksh`):[3]

```
do {
    print data |& "subprogram"
    "subprogram" |& getline results
} while (data left to process)
close("subprogram")
```

The first time an I/O operation is executed using the '`|&`' operator, `gawk` creates a two-way pipeline to a child process that runs the other program. Output created with `print` or `printf` is written to the program's standard input, and output from the program's standard output can be read by the `gawk` program using `getline`. As is the case with processes started by '`|`', the subprogram can be any program, or pipeline of programs, that can be started by the shell.

There are some cautionary items to be aware of:

- As the code inside `gawk` currently stands, the coprocess's standard error goes to the same place that the parent `gawk`'s standard error goes. It is not possible to read the child's standard error separately.
- I/O buffering may be a problem. `gawk` automatically flushes all output down the pipe to the coprocess. However, if the coprocess does not flush its output, `gawk` may hang when doing a `getline` in order to read the coprocess's results. This could lead to a situation known as *deadlock*, where each process is waiting for the other one to do something.

It is possible to close just one end of the two-way pipe to a coprocess, by supplying a second argument to the `close()` function of either `"to"` or `"from"` (see Section 5.8 [Closing

---

[3] This is very different from the same operator in the C shell.

Input and Output Redirections], page 94). These strings tell gawk to close the end of the pipe that sends data to the coprocess or the end that reads from it, respectively.

This is particularly necessary in order to use the system sort utility as part of a coprocess; sort must read *all* of its input data before it can produce any output. The sort program does not receive an end-of-file indication until gawk closes the write end of the pipe.

When you have finished writing data to the sort utility, you can close the "to" end of the pipe, and then start reading sorted data via getline. For example:

```
BEGIN {
    command = "LC_ALL=C sort"
    n = split("abcdefghijklmnopqrstuvwxyz", a, "")

    for (i = n; i > 0; i--)
        print a[i] |& command
    close(command, "to")

    while ((command |& getline line) > 0)
        print "got", line
    close(command)
}
```

This program writes the letters of the alphabet in reverse order, one per line, down the two-way pipe to sort. It then closes the write end of the pipe, so that sort receives an end-of-file indication. This causes sort to sort the data and write the sorted data back to the gawk program. Once all of the data has been read, gawk terminates the coprocess and exits.

As a side note, the assignment 'LC_ALL=C' in the sort command ensures traditional Unix (ASCII) sorting from sort.

You may also use pseudo-ttys (ptys) for two-way communication instead of pipes, if your system supports them. This is done on a per-command basis, by setting a special element in the PROCINFO array (see Section 7.5.2 [Built-in Variables That Convey Information], page 137), like so:

```
command = "sort -nr"           # command, save in convenience variable
PROCINFO[command, "pty"] = 1   # update PROCINFO
print ... |& command       # start two-way pipe
...
```

Using ptys avoids the buffer deadlock issues described earlier, at some loss in performance. If your system does not have ptys, or if all the system's ptys are in use, gawk automatically falls back to using regular pipes.

12.4 Using gawk for Network Programming

EMISTERED:
A host is a host from coast to coast,
and no-one can talk to host that's close,
unless the host that isn't close
is busy hung or dead.

In addition to being able to open a two-way pipeline to a coprocess on the same system (see Section 12.3 [Two-Way Communications with Another Process], page 283), it is possible to make a two-way connection to another process on another system across an IP network connection.

You can think of this as just a *very long* two-way pipeline to a coprocess. The way `gawk` decides that you want to use TCP/IP networking is by recognizing special file names that begin with one of '`/inet/`', '`/inet4/`' or '`/inet6`'.

The full syntax of the special file name is `/net-type/protocol/local-port/remote-host/remote-port`. The components are:

net-type Specifies the kind of Internet connection to make. Use '`/inet4/`' to force IPv4, and '`/inet6/`' to force IPv6. Plain '`/inet/`' (which used to be the only option) uses the system default, most likely IPv4.

protocol The protocol to use over IP. This must be either '`tcp`', or '`udp`', for a TCP or UDP IP connection, respectively. The use of TCP is recommended for most applications.

local-port The local TCP or UDP port number to use. Use a port number of '`0`' when you want the system to pick a port. This is what you should do when writing a TCP or UDP client. You may also use a well-known service name, such as '`smtp`' or '`http`', in which case `gawk` attempts to determine the predefined port number using the C `getaddrinfo()` function.

remote-host
The IP address or fully-qualified domain name of the Internet host to which you want to connect.

remote-port
The TCP or UDP port number to use on the given *remote-host*. Again, use '`0`' if you don't care, or else a well-known service name.

> **NOTE:** Failure in opening a two-way socket will result in a non-fatal error being returned to the calling code. The value of `ERRNO` indicates the error (see Section 7.5.2 [Built-in Variables That Convey Information], page 137).

Consider the following very simple example:

```
BEGIN {
  Service = "/inet/tcp/0/localhost/daytime"
  Service |& getline
  print $0
  close(Service)
}
```

This program reads the current date and time from the local system's TCP '`daytime`' server. It then prints the results and closes the connection.

Because this topic is extensive, the use of `gawk` for TCP/IP programming is documented separately. See *TCP/IP Internetworking with* `gawk`, which comes as part of the `gawk` distribution, for a much more complete introduction and discussion, as well as extensive examples.

12.5 Profiling Your awk Programs

You may produce execution traces of your awk programs. This is done by passing the option --profile to gawk. When gawk has finished running, it creates a profile of your program in a file named awkprof.out. Because it is profiling, it also executes up to 45% slower than gawk normally does.

As shown in the following example, the --profile option can be used to change the name of the file where gawk will write the profile:

```
gawk --profile=myprog.prof -f myprog.awk data1 data2
```

In the above example, gawk places the profile in myprog.prof instead of in awkprof.out.

Here is a sample session showing a simple awk program, its input data, and the results from running gawk with the --profile option. First, the awk program:

```
BEGIN { print "First BEGIN rule" }

END { print "First END rule" }

/foo/ {
    print "matched /foo/, gosh"
    for (i = 1; i <= 3; i++)
        sing()
}

{
    if (/foo/)
        print "if is true"
    else
        print "else is true"
}

BEGIN { print "Second BEGIN rule" }

END { print "Second END rule" }

function sing(    dummy)
{
    print "I gotta be me!"
}
```

Following is the input data:

```
foo
bar
baz
foo
junk
```

Here is the awkprof.out that results from running the gawk profiler on this program and data (this example also illustrates that awk programmers sometimes have to work late):

```
       # gawk profile, created Sun Aug 13 00:00:15 2000

       # BEGIN block(s)

       BEGIN {
    1          print "First BEGIN rule"
    1          print "Second BEGIN rule"
       }

       # Rule(s)

    5  /foo/   { # 2
    2          print "matched /foo/, gosh"
    6          for (i = 1; i <= 3; i++) {
    6                  sing()
               }
       }

    5  {
    5          if (/foo/) { # 2
    2                  print "if is true"
    3          } else {
    3                  print "else is true"
               }
       }

       # END block(s)

       END {
    1          print "First END rule"
    1          print "Second END rule"
       }

       # Functions, listed alphabetically

    6  function sing(dummy)
       {
    6          print "I gotta be me!"
       }
```

This example illustrates many of the basic features of profiling output. They are as follows:

- The program is printed in the order `BEGIN` rule, `BEGINFILE` rule, pattern/action rules, `ENDFILE` rule, `END` rule and functions, listed alphabetically. Multiple `BEGIN` and `END` rules are merged together, as are multiple `BEGINFILE` and `ENDFILE` rules.
- Pattern-action rules have two counts. The first count, to the left of the rule, shows how many times the rule's pattern was *tested*. The second count, to the right of the

rule's opening left brace in a comment, shows how many times the rule's action was *executed*. The difference between the two indicates how many times the rule's pattern evaluated to false.

- Similarly, the count for an `if-else` statement shows how many times the condition was tested. To the right of the opening left brace for the `if`'s body is a count showing how many times the condition was true. The count for the `else` indicates how many times the test failed.
- The count for a loop header (such as `for` or `while`) shows how many times the loop test was executed. (Because of this, you can't just look at the count on the first statement in a rule to determine how many times the rule was executed. If the first statement is a loop, the count is misleading.)
- For user-defined functions, the count next to the `function` keyword indicates how many times the function was called. The counts next to the statements in the body show how many times those statements were executed.
- The layout uses "K&R" style with TABs. Braces are used everywhere, even when the body of an `if`, `else`, or loop is only a single statement.
- Parentheses are used only where needed, as indicated by the structure of the program and the precedence rules. For example, '`(3 + 5) * 4`' means add three plus five, then multiply the total by four. However, '`3 + 5 * 4`' has no parentheses, and means '`3 + (5 * 4)`'.
- Parentheses are used around the arguments to `print` and `printf` only when the `print` or `printf` statement is followed by a redirection. Similarly, if the target of a redirection isn't a scalar, it gets parenthesized.
- `gawk` supplies leading comments in front of the `BEGIN` and `END` rules, the `BEGINFILE` and `ENDFILE` rules, the pattern/action rules, and the functions.

The profiled version of your program may not look exactly like what you typed when you wrote it. This is because `gawk` creates the profiled version by "pretty printing" its internal representation of the program. The advantage to this is that `gawk` can produce a standard representation. The disadvantage is that all source-code comments are lost, as are the distinctions among multiple `BEGIN`, `END`, `BEGINFILE`, and `ENDFILE` rules. Also, things such as:

```
/foo/
```

come out as:

```
/foo/   {
    print $0
}
```

which is correct, but possibly surprising.

Besides creating profiles when a program has completed, `gawk` can produce a profile while it is running. This is useful if your `awk` program goes into an infinite loop and you want to see what has been executed. To use this feature, run `gawk` with the `--profile` option in the background:

```
$ gawk --profile -f myprog &
[1] 13992
```

The shell prints a job number and process ID number; in this case, 13992. Use the `kill` command to send the `USR1` signal to `gawk`:

```
$ kill -USR1 13992
```

As usual, the profiled version of the program is written to `awkprof.out`, or to a different file if one specified with the `--profile` option.

Along with the regular profile, as shown earlier, the profile includes a trace of any active functions:

```
# Function Call Stack:

#   3. baz
#   2. bar
#   1. foo
# -- main --
```

You may send `gawk` the `USR1` signal as many times as you like. Each time, the profile and function call trace are appended to the output profile file.

If you use the `HUP` signal instead of the `USR1` signal, `gawk` produces the profile and the function call trace and then exits.

When `gawk` runs on MS-Windows systems, it uses the `INT` and `QUIT` signals for producing the profile and, in the case of the `INT` signal, `gawk` exits. This is because these systems don't support the `kill` command, so the only signals you can deliver to a program are those generated by the keyboard. The `INT` signal is generated by the *`Ctrl-C`* or *`Ctrl-BREAK`* key, while the `QUIT` signal is generated by the *`Ctrl-\`* key.

Finally, `gawk` also accepts another option, `--pretty-print`. When called this way, `gawk` "pretty prints" the program into `awkprof.out`, without any execution counts.

13 Internationalization with gawk

Once upon a time, computer makers wrote software that worked only in English. Eventually, hardware and software vendors noticed that if their systems worked in the native languages of non-English-speaking countries, they were able to sell more systems. As a result, internationalization and localization of programs and software systems became a common practice.

For many years, the ability to provide internationalization was largely restricted to programs written in C and C++. This chapter describes the underlying library gawk uses for internationalization, as well as how gawk makes internationalization features available at the awk program level. Having internationalization available at the awk level gives software developers additional flexibility—they are no longer forced to write in C or C++ when internationalization is a requirement.

13.1 Internationalization and Localization

Internationalization means writing (or modifying) a program once, in such a way that it can use multiple languages without requiring further source-code changes. *Localization* means providing the data necessary for an internationalized program to work in a particular language. Most typically, these terms refer to features such as the language used for printing error messages, the language used to read responses, and information related to how numerical and monetary values are printed and read.

13.2 GNU gettext

The facilities in GNU gettext focus on messages; strings printed by a program, either directly or via formatting with printf or sprintf().[1]

When using GNU gettext, each application has its own *text domain*. This is a unique name, such as 'kpilot' or 'gawk', that identifies the application. A complete application may have multiple components—programs written in C or C++, as well as scripts written in sh or awk. All of the components use the same text domain.

To make the discussion concrete, assume we're writing an application named guide. Internationalization consists of the following steps, in this order:

1. The programmer goes through the source for all of guide's components and marks each string that is a candidate for translation. For example, "'-F': option required" is a good candidate for translation. A table with strings of option names is not (e.g., gawk's --profile option should remain the same, no matter what the local language).
2. The programmer indicates the application's text domain ("guide") to the gettext library, by calling the textdomain() function.
3. Messages from the application are extracted from the source code and collected into a portable object template file (guide.pot), which lists the strings and their translations. The translations are initially empty. The original (usually English) messages serve as the key for lookup of the translations.

---

[1] For some operating systems, the gawk port doesn't support GNU gettext. Therefore, these features are not available if you are using one of those operating systems. Sorry.

4. For each language with a translator, guide.pot is copied to a portable object file (.po) and translations are created and shipped with the application. For example, there might be a fr.po for a French translation.
5. Each language's .po file is converted into a binary message object (.gmo) file. A message object file contains the original messages and their translations in a binary format that allows fast lookup of translations at runtime.
6. When guide is built and installed, the binary translation files are installed in a standard place.
7. For testing and development, it is possible to tell gettext to use .gmo files in a different directory than the standard one by using the bindtextdomain() function.
8. At runtime, guide looks up each string via a call to gettext(). The returned string is the translated string if available, or the original string if not.
9. If necessary, it is possible to access messages from a different text domain than the one belonging to the application, without having to switch the application's default text domain back and forth.

In C (or C++), the string marking and dynamic translation lookup are accomplished by wrapping each string in a call to gettext():

```
printf("%s", gettext("Don't Panic!\n"));
```

The tools that extract messages from source code pull out all strings enclosed in calls to gettext().

The GNU gettext developers, recognizing that typing 'gettext(...)' over and over again is both painful and ugly to look at, use the macro '_' (an underscore) to make things easier:

```
/* In the standard header file: */
#define _(str) gettext(str)

/* In the program text: */
printf("%s", _("Don't Panic!\n"));
```

This reduces the typing overhead to just three extra characters per string and is considerably easier to read as well.

There are locale *categories* for different types of locale-related information. The defined locale categories that gettext knows about are:

LC_MESSAGES
: Text messages. This is the default category for gettext operations, but it is possible to supply a different one explicitly, if necessary. (It is almost never necessary to supply a different category.)

LC_COLLATE
: Text-collation information; i.e., how different characters and/or groups of characters sort in a given language.

LC_CTYPE
: Character-type information (alphabetic, digit, upper- or lowercase, and so on). This information is accessed via the POSIX character classes in regular expressions, such as /[[:alnum:]]/ (see Section 3.3 [Regular Expression Operators], page 46).

`LC_MONETARY`
: Monetary information, such as the currency symbol, and whether the symbol goes before or after a number.

`LC_NUMERIC`
: Numeric information, such as which characters to use for the decimal point and the thousands separator.[2]

`LC_RESPONSE`
: Response information, such as how "yes" and "no" appear in the local language, and possibly other information as well.

`LC_TIME` Time- and date-related information, such as 12- or 24-hour clock, month printed before or after the day in a date, local month abbreviations, and so on.

`LC_ALL` All of the above. (Not too useful in the context of `gettext`.)

13.3 Internationalizing awk Programs

`gawk` provides the following variables and functions for internationalization:

`TEXTDOMAIN`
: This variable indicates the application's text domain. For compatibility with GNU `gettext`, the default value is `"messages"`.

`_"your message here"`
: String constants marked with a leading underscore are candidates for translation at runtime. String constants without a leading underscore are not translated.

`dcgettext(`*`string`* [`,` *`domain`* [`,` *`category`*]]`)`
: Return the translation of *string* in text domain *domain* for locale category *category*. The default value for *domain* is the current value of `TEXTDOMAIN`. The default value for *category* is `"LC_MESSAGES"`.

If you supply a value for *category*, it must be a string equal to one of the known locale categories described in the previous section. You must also supply a text domain. Use `TEXTDOMAIN` if you want to use the current domain.

> **CAUTION:** The order of arguments to the `awk` version of the `dcgettext()` function is purposely different from the order for the C version. The `awk` version's order was chosen to be simple and to allow for reasonable `awk`-style default arguments.

`dcngettext(`*`string1`*`,` *`string2`*`,` *`number`* [`,` *`domain`* [`,` *`category`*]]`)`
: Return the plural form used for *number* of the translation of *string1* and *string2* in text domain *domain* for locale category *category*. *string1* is the English singular variant of a message, and *string2* the English plural variant of the same message. The default value for *domain* is the current value of `TEXTDOMAIN`. The default value for *category* is `"LC_MESSAGES"`.

The same remarks about argument order as for the `dcgettext()` function apply.

[2] Americans use a comma every three decimal places and a period for the decimal point, while many Europeans do exactly the opposite: 1,234.56 versus 1.234,56.

`bindtextdomain(directory [, domain])`
: Change the directory in which `gettext` looks for `.gmo` files, in case they will not or cannot be placed in the standard locations (e.g., during testing). Return the directory in which *domain* is "bound."

  The default *domain* is the value of `TEXTDOMAIN`. If *directory* is the null string (`""`), then `bindtextdomain()` returns the current binding for the given *domain*.

To use these facilities in your `awk` program, follow the steps outlined in the previous section, like so:

1. Set the variable `TEXTDOMAIN` to the text domain of your program. This is best done in a `BEGIN` rule (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122), or it can also be done via the `-v` command-line option (see Section 2.2 [Command-Line Options], page 29):

   ```
   BEGIN {
       TEXTDOMAIN = "guide"
       ...
   }
   ```

2. Mark all translatable strings with a leading underscore ('`_`') character. It *must* be adjacent to the opening quote of the string. For example:

   ```
   print _"hello, world"
   x = _"you goofed"
   printf(_"Number of users is %d\n", nusers)
   ```

3. If you are creating strings dynamically, you can still translate them, using the `dcgettext()` built-in function:

   ```
   message = nusers " users logged in"
   message = dcgettext(message, "adminprog")
   print message
   ```

   Here, the call to `dcgettext()` supplies a different text domain (`"adminprog"`) in which to find the message, but it uses the default `"LC_MESSAGES"` category.

4. During development, you might want to put the `.gmo` file in a private directory for testing. This is done with the `bindtextdomain()` built-in function:

   ```
   BEGIN {
      TEXTDOMAIN = "guide"   # our text domain
      if (Testing) {
          # where to find our files
          bindtextdomain("testdir")
          # joe is in charge of adminprog
          bindtextdomain("../joe/testdir", "adminprog")
      }
      ...
   }
   ```

See Section 13.5 [A Simple Internationalization Example], page 297, for an example program showing the steps to create and use translations from `awk`.

13.4 Translating awk Programs

Once a program's translatable strings have been marked, they must be extracted to create the initial .po file. As part of translation, it is often helpful to rearrange the order in which arguments to printf are output.

gawk's --gen-pot command-line option extracts the messages and is discussed next. After that, printf's ability to rearrange the order for printf arguments at runtime is covered.

13.4.1 Extracting Marked Strings

Once your awk program is working, and all the strings have been marked and you've set (and perhaps bound) the text domain, it is time to produce translations. First, use the --gen-pot command-line option to create the initial .pot file:

```
$ gawk --gen-pot -f guide.awk > guide.pot
```

When run with --gen-pot, gawk does not execute your program. Instead, it parses it as usual and prints all marked strings to standard output in the format of a GNU gettext Portable Object file. Also included in the output are any constant strings that appear as the first argument to dcgettext() or as the first and second argument to dcngettext().[3] See Section 13.5 [A Simple Internationalization Example], page 297, for the full list of steps to go through to create and test translations for guide.

13.4.2 Rearranging printf Arguments

Format strings for printf and sprintf() (see Section 5.5 [Using printf Statements for Fancier Printing], page 84) present a special problem for translation. Consider the following:[4]

```
printf(_"String ‘%s’ has %d characters\n",
          string, length(string)))
```

A possible German translation for this might be:

```
"%d Zeichen lang ist die Zeichenkette ‘%s’\n"
```

The problem should be obvious: the order of the format specifications is different from the original! Even though gettext() can return the translated string at runtime, it cannot change the argument order in the call to printf.

To solve this problem, printf format specifiers may have an additional optional element, which we call a *positional specifier*. For example:

```
"%2$d Zeichen lang ist die Zeichenkette ‘%1$s’\n"
```

Here, the positional specifier consists of an integer count, which indicates which argument to use, and a '$'. Counts are one-based, and the format string itself is *not* included. Thus, in the following example, 'string' is the first argument and 'length(string)' is the second:

```
$ gawk 'BEGIN {
>     string = "Dont Panic"
>     printf _"%2$d characters live in \"%1$s\"\n",
>                         string, length(string)
```

---

[3] The xgettext utility that comes with GNU gettext can handle .awk files.

[4] This example is borrowed from the GNU gettext manual.

```
> }'
⊣ 10 characters live in "Dont Panic"
```

If present, positional specifiers come first in the format specification, before the flags, the field width, and/or the precision.

Positional specifiers can be used with the dynamic field width and precision capability:

```
$ gawk 'BEGIN {
>    printf("%*.*s\n", 10, 20, "hello")
>    printf("%3$*2$.*1$s\n", 20, 10, "hello")
> }'
⊣      hello
⊣      hello
```

> **NOTE:** When using '`*`' with a positional specifier, the '`*`' comes first, then the integer position, and then the '`$`'. This is somewhat counterintuitive.

`gawk` does not allow you to mix regular format specifiers and those with positional specifiers in the same string:

```
$ gawk 'BEGIN { printf _"%d %3$s\n", 1, 2, "hi" }'
error  gawk: cmd. line:1: fatal: must use 'count$' on all formats or none
```

> **NOTE:** There are some pathological cases that `gawk` may fail to diagnose. In such cases, the output may not be what you expect. It's still a bad idea to try mixing them, even if `gawk` doesn't detect it.

Although positional specifiers can be used directly in `awk` programs, their primary purpose is to help in producing correct translations of format strings into languages different from the one in which the program is first written.

13.4.3 `awk` Portability Issues

`gawk`'s internationalization features were purposely chosen to have as little impact as possible on the portability of `awk` programs that use them to other versions of `awk`. Consider this program:

```
BEGIN {
    TEXTDOMAIN = "guide"
    if (Test_Guide)   # set with -v
        bindtextdomain("/test/guide/messages")
    print _"don't panic!"
}
```

As written, it won't work on other versions of `awk`. However, it is actually almost portable, requiring very little change:

- Assignments to `TEXTDOMAIN` won't have any effect, since `TEXTDOMAIN` is not special in other `awk` implementations.
- Non-GNU versions of `awk` treat marked strings as the concatenation of a variable named `_` with the string following it.[5] Typically, the variable `_` has the null string (`""`) as its value, leaving the original string constant as the result.

[5] This is good fodder for an "Obfuscated `awk`" contest.

- By defining "dummy" functions to replace dcgettext(), dcngettext() and bindtextdomain(), the awk program can be made to run, but all the messages are output in the original language. For example:

```
function bindtextdomain(dir, domain)
{
    return dir
}

function dcgettext(string, domain, category)
{
    return string
}

function dcngettext(string1, string2, number, domain, category)
{
    return (number == 1 ? string1 : string2)
}
```

- The use of positional specifications in printf or sprintf() is *not* portable. To support gettext() at the C level, many systems' C versions of sprintf() do support positional specifiers. But it works only if enough arguments are supplied in the function call. Many versions of awk pass printf formats and arguments unchanged to the underlying C library version of sprintf(), but only one format and argument at a time. What happens if a positional specification is used is anybody's guess. However, since the positional specifications are primarily for use in *translated* format strings, and since non-GNU awks never retrieve the translated string, this should not be a problem in practice.

13.5 A Simple Internationalization Example

Now let's look at a step-by-step example of how to internationalize and localize a simple awk program, using guide.awk as our original source:

```
BEGIN {
    TEXTDOMAIN = "guide"
    bindtextdomain(".")  # for testing
    print _"Don't Panic"
    print _"The Answer Is", 42
    print "Pardon me, Zaphod who?"
}
```

Run 'gawk --gen-pot' to create the .pot file:

```
$ gawk --gen-pot -f guide.awk > guide.pot
```

This produces:

```
#: guide.awk:4
msgid "Don't Panic"
msgstr ""

#: guide.awk:5
```

```
msgid "The Answer Is"
msgstr ""
```

This original portable object template file is saved and reused for each language into which the application is translated. The `msgid` is the original string and the `msgstr` is the translation.

> **NOTE:** Strings not marked with a leading underscore do not appear in the `guide.pot` file.

Next, the messages must be translated. Here is a translation to a hypothetical dialect of English, called "Mellow":[6]

```
$ cp guide.pot guide-mellow.po
Add translations to guide-mellow.po ...
```

Following are the translations:

```
#: guide.awk:4
msgid "Don't Panic"
msgstr "Hey man, relax!"

#: guide.awk:5
msgid "The Answer Is"
msgstr "Like, the scoop is"
```

The next step is to make the directory to hold the binary message object file and then to create the `guide.gmo` file. The directory layout shown here is standard for GNU `gettext` on GNU/Linux systems. Other versions of `gettext` may use a different layout:

```
$ mkdir en_US en_US/LC_MESSAGES
```

The `msgfmt` utility does the conversion from human-readable `.po` file to machine-readable `.gmo` file. By default, `msgfmt` creates a file named `messages`. This file must be renamed and placed in the proper directory so that `gawk` can find it:

```
$ msgfmt guide-mellow.po
$ mv messages en_US/LC_MESSAGES/guide.gmo
```

Finally, we run the program to test it:

```
$ gawk -f guide.awk
⊣ Hey man, relax!
⊣ Like, the scoop is 42
⊣ Pardon me, Zaphod who?
```

If the three replacement functions for `dcgettext()`, `dcngettext()` and `bindtextdomain()` (see Section 13.4.3 [`awk` Portability Issues], page 296) are in a file named `libintl.awk`, then we can run `guide.awk` unchanged as follows:

```
$ gawk --posix -f guide.awk -f libintl.awk
⊣ Don't Panic
⊣ The Answer Is 42
⊣ Pardon me, Zaphod who?
```

[6] Perhaps it would be better if it were called "Hippy." Ah, well.

13.6 gawk Can Speak Your Language

gawk itself has been internationalized using the GNU gettext package. (GNU gettext is described in complete detail in *GNU gettext tools*.) As of this writing, the latest version of GNU gettext is version 0.18.2.1 (ftp://ftp.gnu.org/gnu/gettext/gettext-0.18.2.1.tar.gz).

If a translation of gawk's messages exists, then gawk produces usage messages, warnings, and fatal errors in the local language.

14 Debugging awk Programs

It would be nice if computer programs worked perfectly the first time they were run, but in real life, this rarely happens for programs of any complexity. Thus, most programming languages have facilities available for "debugging" programs, and now awk is no exception.

The gawk debugger is purposely modeled after the GNU Debugger (GDB) (http://www.gnu.org/software/gdb/) command-line debugger. If you are familiar with GDB, learning how to use gawk for debugging your program is easy.

14.1 Introduction to gawk Debugger

This section introduces debugging in general and begins the discussion of debugging in gawk.

14.1.1 Debugging in General

(If you have used debuggers in other languages, you may want to skip ahead to the next section on the specific features of the awk debugger.)

Of course, a debugging program cannot remove bugs for you, since it has no way of knowing what you or your users consider a "bug" and what is a "feature." (Sometimes, we humans have a hard time with this ourselves.) In that case, what can you expect from such a tool? The answer to that depends on the language being debugged, but in general, you can expect at least the following:

- The ability to watch a program execute its instructions one by one, giving you, the programmer, the opportunity to think about what is happening on a time scale of seconds, minutes, or hours, rather than the nanosecond time scale at which the code usually runs.
- The opportunity to not only passively observe the operation of your program, but to control it and try different paths of execution, without having to change your source files.
- The chance to see the values of data in the program at any point in execution, and also to change that data on the fly, to see how that affects what happens afterwards. (This often includes the ability to look at internal data structures besides the variables you actually defined in your code.)
- The ability to obtain additional information about your program's state or even its internal structure.

All of these tools provide a great amount of help in using your own skills and understanding of the goals of your program to find where it is going wrong (or, for that matter, to better comprehend a perfectly functional program that you or someone else wrote).

14.1.2 Additional Debugging Concepts

Before diving in to the details, we need to introduce several important concepts that apply to just about all debuggers. The following list defines terms used throughout the rest of this chapter.

Stack Frame

Programs generally call functions during the course of their execution. One function can call another, or a function can call itself (recursion). You can view the chain of called functions (main program calls A, which calls B, which calls C), as a stack of executing functions: the currently running function is the topmost one on the stack, and when it finishes (returns), the next one down then becomes the active function. Such a stack is termed a *call stack*.

For each function on the call stack, the system maintains a data area that contains the function's parameters, local variables, and return value, as well as any other "bookkeeping" information needed to manage the call stack. This data area is termed a *stack frame*.

`gawk` also follows this model, and gives you access to the call stack and to each stack frame. You can see the call stack, as well as from where each function on the stack was invoked. Commands that print the call stack print information about each stack frame (as detailed later on).

Breakpoint

During debugging, you often wish to let the program run until it reaches a certain point, and then continue execution from there one statement (or instruction) at a time. The way to do this is to set a *breakpoint* within the program. A breakpoint is where the execution of the program should break off (stop), so that you can take over control of the program's execution. You can add and remove as many breakpoints as you like.

Watchpoint

A watchpoint is similar to a breakpoint. The difference is that breakpoints are oriented around the code: stop when a certain point in the code is reached. A watchpoint, however, specifies that program execution should stop when a *data value* is changed. This is useful, since sometimes it happens that a variable receives an erroneous value, and it's hard to track down where this happens just by looking at the code. By using a watchpoint, you can stop whenever a variable is assigned to, and usually find the errant code quite quickly.

14.1.3 Awk Debugging

Debugging an `awk` program has some specific aspects that are not shared with other programming languages.

First of all, the fact that `awk` programs usually take input line-by-line from a file or files and operate on those lines using specific rules makes it especially useful to organize viewing the execution of the program in terms of these rules. As we will see, each `awk` rule is treated almost like a function call, with its own specific block of instructions.

In addition, since `awk` is by design a very concise language, it is easy to lose sight of everything that is going on "inside" each line of `awk` code. The debugger provides the opportunity to look at the individual primitive instructions carried out by the higher-level `awk` commands.

14.2 Sample Debugging Session

In order to illustrate the use of `gawk` as a debugger, let's look at a sample debugging session. We will use the `awk` implementation of the POSIX `uniq` command described earlier (see Section 11.2.6 [Printing Nonduplicated Lines of Text], page 245) as our example.

14.2.1 How to Start the Debugger

Starting the debugger is almost exactly like running awk, except you have to pass an additional option --debug or the corresponding short option -D. The file(s) containing the program and any supporting code are given on the command line as arguments to one or more -f options. (gawk is not designed to debug command-line programs, only programs contained in files.) In our case, we invoke the debugger like this:

```
$ gawk -D -f getopt.awk -f join.awk -f uniq.awk inputfile
```

where both getopt.awk and uniq.awk are in $AWKPATH. (Experienced users of GDB or similar debuggers should note that this syntax is slightly different from what they are used to. With the gawk debugger, you give the arguments for running the program in the command line to the debugger rather than as part of the run command at the debugger prompt.)

Instead of immediately running the program on inputfile, as gawk would ordinarily do, the debugger merely loads all the program source files, compiles them internally, and then gives us a prompt:

```
gawk>
```

from which we can issue commands to the debugger. At this point, no code has been executed.

14.2.2 Finding the Bug

Let's say that we are having a problem using (a faulty version of) uniq.awk in the "field-skipping" mode, and it doesn't seem to be catching lines which should be identical when skipping the first field, such as:

```
awk is a wonderful program!
gawk is a wonderful program!
```

This could happen if we were thinking (C-like) of the fields in a record as being numbered in a zero-based fashion, so instead of the lines:

```
clast = join(alast, fcount+1, n)
cline = join(aline, fcount+1, m)
```

we wrote:

```
clast = join(alast, fcount, n)
cline = join(aline, fcount, m)
```

The first thing we usually want to do when trying to investigate a problem like this is to put a breakpoint in the program so that we can watch it at work and catch what it is doing wrong. A reasonable spot for a breakpoint in uniq.awk is at the beginning of the function are_equal(), which compares the current line with the previous one. To set the breakpoint, use the b (breakpoint) command:

```
gawk> b are_equal
⊣ Breakpoint 1 set at file ‘awklib/eg/prog/uniq.awk’, line 64
```

The debugger tells us the file and line number where the breakpoint is. Now type 'r' or 'run' and the program runs until it hits the breakpoint for the first time:

```
gawk> r
⊣ Starting program:
```

```
⊣ Stopping in Rule ...
⊣ Breakpoint 1, are_equal(n, m, clast, cline, alast, aline)
        at ‘awklib/eg/prog/uniq.awk’:64
⊣ 64          if (fcount == 0 && charcount == 0)
gawk>
```

Now we can look at what's going on inside our program. First of all, let's see how we got to where we are. At the prompt, we type '`bt`' (short for "backtrace"), and the debugger responds with a listing of the current stack frames:

```
gawk> bt
⊣ #0  are_equal(n, m, clast, cline, alast, aline)
        at ‘awklib/eg/prog/uniq.awk’:69
⊣ #1  in main() at ‘awklib/eg/prog/uniq.awk’:89
```

This tells us that `are_equal()` was called by the main program at line 89 of `uniq.awk`. (This is not a big surprise, since this is the only call to `are_equal()` in the program, but in more complex programs, knowing who called a function and with what parameters can be the key to finding the source of the problem.)

Now that we're in `are_equal()`, we can start looking at the values of some variables. Let's say we type '`p n`' (`p` is short for "print"). We would expect to see the value of `n`, a parameter to `are_equal()`. Actually, the debugger gives us:

```
gawk> p n
⊣ n = untyped variable
```

In this case, `n` is an uninitialized local variable, since the function was called without arguments (see Section 6.4 [Function Calls], page 115).

A more useful variable to display might be the current record:

```
gawk> p $0
⊣ $0 = string ("gawk is a wonderful program!")
```

This might be a bit puzzling at first since this is the second line of our test input above. Let's look at `NR`:

```
gawk> p NR
⊣ NR = number (2)
```

So we can see that `are_equal()` was only called for the second record of the file. Of course, this is because our program contained a rule for '`NR == 1`':

```
NR == 1 {
    last = $0
    next
}
```

OK, let's just check that that rule worked correctly:

```
gawk> p last
⊣ last = string ("awk is a wonderful program!")
```

Everything we have done so far has verified that the program has worked as planned, up to and including the call to `are_equal()`, so the problem must be inside this function. To investigate further, we must begin "stepping through" the lines of `are_equal()`. We start by typing '`n`' (for "next"):

```
gawk> n
⊣ 67          if (fcount > 0) {
```

This tells us that `gawk` is now ready to execute line 67, which decides whether to give the lines the special "field skipping" treatment indicated by the `-f` command-line option. (Notice that we skipped from where we were before at line 64 to here, since the condition in line 64

```
if (fcount == 0 && charcount == 0)
```

was false.)

Continuing to step, we now get to the splitting of the current and last records:

```
gawk> n
⊣ 68              n = split(last, alast)
gawk> n
⊣ 69              m = split($0, aline)
```

At this point, we should be curious to see what our records were split into, so we try to look:

```
gawk> p n m alast aline
⊣ n = number (5)
⊣ m = number (5)
⊣ alast = array, 5 elements
⊣ aline = array, 5 elements
```

(The `p` command can take more than one argument, similar to `awk`'s `print` statement.)

This is kind of disappointing, though. All we found out is that there are five elements in each of our arrays. Useful enough (we now know that none of the words were accidentally left out), but what if we want to see inside the array?

The first choice would be to use subscripts:

```
gawk> p alast[0]
⊣ "0" not in array 'alast'
```

Oops!

```
gawk> p alast[1]
⊣ alast["1"] = string ("awk")
```

This would be kind of slow for a 100-member array, though, so `gawk` provides a shortcut (reminiscent of another language not to be mentioned):

```
gawk> p @alast
⊣ alast["1"] = string ("awk")
⊣ alast["2"] = string ("is")
⊣ alast["3"] = string ("a")
⊣ alast["4"] = string ("wonderful")
⊣ alast["5"] = string ("program!")
```

It looks like we got this far OK. Let's take another step or two:

```
gawk> n
⊣ 70              clast = join(alast, fcount, n)
gawk> n
⊣ 71              cline = join(aline, fcount, m)
```

Well, here we are at our error (sorry to spoil the suspense). What we had in mind was to join the fields starting from the second one to make the virtual record to compare, and if the first field was numbered zero, this would work. Let's look at what we've got:

```
gawk> p cline clast
⊣ cline = string ("gawk is a wonderful program!")
⊣ clast = string ("awk is a wonderful program!")
```

Hey, those look pretty familiar! They're just our original, unaltered, input records. A little thinking (the human brain is still the best debugging tool), and we realize that we were off by one!

We get out of the debugger:

```
gawk> q
⊣ The program is running. Exit anyway (y/n)? y
```

Then we get into an editor:

```
clast = join(alast, fcount+1, n)
cline = join(aline, fcount+1, m)
```

and problem solved!

14.3 Main Debugger Commands

The `gawk` debugger command set can be divided into the following categories:

- Breakpoint control
- Execution control
- Viewing and changing data
- Working with the stack
- Getting information
- Miscellaneous

Each of these are discussed in the following subsections. In the following descriptions, commands which may be abbreviated show the abbreviation on a second description line. A debugger command name may also be truncated if that partial name is unambiguous. The debugger has the built-in capability to automatically repeat the previous command when just hitting `Enter`. This works for the commands `list`, `next`, `nexti`, `step`, `stepi` and `continue` executed without any argument.

14.3.1 Control of Breakpoints

As we saw above, the first thing you probably want to do in a debugging session is to get your breakpoints set up, since otherwise your program will just run as if it was not under the debugger. The commands for controlling breakpoints are:

`break` [[*filename*`:`]*n* `|` *function*] [`"`*`expression`*`"`]
`b` [[*filename*`:`]*n* `|` *function*] [`"`*`expression`*`"`]

Without any argument, set a breakpoint at the next instruction to be executed in the selected stack frame. Arguments can be one of the following:

n Set a breakpoint at line number *n* in the current source file.

filename:*n*
Set a breakpoint at line number *n* in source file *filename*.

function Set a breakpoint at entry to (the first instruction of) function *function*.

Each breakpoint is assigned a number which can be used to delete it from the breakpoint list using the `delete` command.

With a breakpoint, you may also supply a condition. This is an `awk` expression (enclosed in double quotes) that the debugger evaluates whenever the breakpoint is reached. If the condition is true, then the debugger stops execution and prompts for a command. Otherwise, it continues executing the program.

`clear` [[*filename*:]*n* | *function*]
Without any argument, delete any breakpoint at the next instruction to be executed in the selected stack frame. If the program stops at a breakpoint, this deletes that breakpoint so that the program does not stop at that location again. Arguments can be one of the following:

n Delete breakpoint(s) set at line number *n* in the current source file.

filename:*n*
Delete breakpoint(s) set at line number *n* in source file *filename*.

function Delete breakpoint(s) set at entry to function *function*.

`condition` *n* "*expression*"
Add a condition to existing breakpoint or watchpoint *n*. The condition is an `awk` expression that the debugger evaluates whenever the breakpoint or watchpoint is reached. If the condition is true, then the debugger stops execution and prompts for a command. Otherwise, the debugger continues executing the program. If the condition expression is not specified, any existing condition is removed; i.e., the breakpoint or watchpoint is made unconditional.

`delete` [*n1 n2* ...] [*n*–*m*]
`d` [*n1 n2* ...] [*n*–*m*]
Delete specified breakpoints or a range of breakpoints. Deletes all defined breakpoints if no argument is supplied.

`disable` [*n1 n2* ... | *n*–*m*]
Disable specified breakpoints or a range of breakpoints. Without any argument, disables all breakpoints.

`enable` [`del` | `once`] [*n1 n2* ...] [*n*–*m*]
`e` [`del` | `once`] [*n1 n2* ...] [*n*–*m*]
Enable specified breakpoints or a range of breakpoints. Without any argument, enables all breakpoints. Optionally, you can specify how to enable the breakpoint:

`del` Enable the breakpoint(s) temporarily, then delete it when the program stops at the breakpoint.

`once` Enable the breakpoint(s) temporarily, then disable it when the program stops at the breakpoint.

`ignore` *n count*
: Ignore breakpoint number *n* the next *count* times it is hit.

`tbreak` [[*filename*`:`]*n* `|` *function*]
`t` [[*filename*`:`]*n* `|` *function*]
: Set a temporary breakpoint (enabled for only one stop). The arguments are the same as for `break`.

14.3.2 Control of Execution

Now that your breakpoints are ready, you can start running the program and observing its behavior. There are more commands for controlling execution of the program than we saw in our earlier example:

`commands` [*n*]
`silent`
`...`
`end`
: Set a list of commands to be executed upon stopping at a breakpoint or watchpoint. *n* is the breakpoint or watchpoint number. Without a number, the last one set is used. The actual commands follow, starting on the next line, and terminated by the `end` command. If the command `silent` is in the list, the usual messages about stopping at a breakpoint and the source line are not printed. Any command in the list that resumes execution (e.g., `continue`) terminates the list (an implicit `end`), and subsequent commands are ignored. For example:

```
gawk> commands
> silent
> printf "A silent breakpoint; i = %d\n", i
> info locals
> set i = 10
> continue
> end
gawk>
```

`continue` [*count*]
`c` [*count*]
: Resume program execution. If continued from a breakpoint and *count* is specified, ignores the breakpoint at that location the next *count* times before stopping.

`finish`
: Execute until the selected stack frame returns. Print the returned value.

`next` [*count*]
`n` [*count*]
: Continue execution to the next source line, stepping over function calls. The argument *count* controls how many times to repeat the action, as in `step`.

`nexti` [*count*]
`ni` [*count*]
: Execute one (or *count*) instruction(s), stepping over function calls.

`return` [*value*]
: Cancel execution of a function call. If *value* (either a string or a number) is specified, it is used as the function's return value. If used in a frame other than the innermost one (the currently executing function, i.e., frame number

0), discard all inner frames in addition to the selected one, and the caller of that frame becomes the innermost frame.

`run`
`r` Start/restart execution of the program. When restarting, the debugger retains the current breakpoints, watchpoints, command history, automatic display variables, and debugger options.

`step` [*count*]
`s` [*count*] Continue execution until control reaches a different source line in the current stack frame. `step` steps inside any function called within the line. If the argument *count* is supplied, steps that many times before stopping, unless it encounters a breakpoint or watchpoint.

`stepi` [*count*]
`si` [*count*] Execute one (or *count*) instruction(s), stepping inside function calls. (For illustration of what is meant by an "instruction" in `gawk`, see the output shown under `dump` in Section 14.3.6 [Miscellaneous Commands], page 312.)

`until` [[*filename*`:`]*n* `|` *function*]
`u` [[*filename*`:`]*n* `|` *function*]
Without any argument, continue execution until a line past the current line in current stack frame is reached. With an argument, continue execution until the specified location is reached, or the current stack frame returns.

14.3.3 Viewing and Changing Data

The commands for viewing and changing variables inside of `gawk` are:

`display` [*var* `|` `$`*n*]
Add variable *var* (or field `$n`) to the display list. The value of the variable or field is displayed each time the program stops. Each variable added to the list is identified by a unique number:

```
gawk> display x
⊣ 10: x = 1
```

displays the assigned item number, the variable name and its current value. If the display variable refers to a function parameter, it is silently deleted from the list as soon as the execution reaches a context where no such variable of the given name exists. Without argument, `display` displays the current values of items on the list.

`eval "`*awk statements*`"`
Evaluate *awk statements* in the context of the running program. You can do anything that an `awk` program would do: assign values to variables, call functions, and so on.

`eval` *param*, . . .
awk statements
`end` This form of `eval` is similar, but it allows you to define "local variables" that exist in the context of the *awk statements*, instead of using variables or function parameters defined by the program.

`print` *var1*[`,` *var2* ...]
`p` *var1*[`,` *var2* ...]

Print the value of a `gawk` variable or field. Fields must be referenced by constants:

```
gawk> print $3
```

This prints the third field in the input record (if the specified field does not exist, it prints '`Null field`'). A variable can be an array element, with the subscripts being constant values. To print the contents of an array, prefix the name of the array with the '`@`' symbol:

```
gawk> print @a
```

This prints the indices and the corresponding values for all elements in the array `a`.

`printf` *format* [`,` *arg* ...]

Print formatted text. The *format* may include escape sequences, such as '`\n`' (see Section 3.2 [Escape Sequences], page 44). No newline is printed unless one is specified.

`set` *var*`=`*value*

Assign a constant (number or string) value to an `awk` variable or field. String values must be enclosed between double quotes (`"..."`).

You can also set special `awk` variables, such as `FS`, `NF`, `NR`, etc.

`watch` *var* `|` `$`*n* [`"`*expression*`"`]
`w` *var* `|` `$`*n* [`"`*expression*`"`]

Add variable *var* (or field `$`*n*) to the watch list. The debugger then stops whenever the value of the variable or field changes. Each watched item is assigned a number which can be used to delete it from the watch list using the `unwatch` command.

With a watchpoint, you may also supply a condition. This is an `awk` expression (enclosed in double quotes) that the debugger evaluates whenever the watchpoint is reached. If the condition is true, then the debugger stops execution and prompts for a command. Otherwise, `gawk` continues executing the program.

`undisplay` [*n*]

Remove item number *n* (or all items, if no argument) from the automatic display list.

`unwatch` [*n*]

Remove item number *n* (or all items, if no argument) from the watch list.

14.3.4 Dealing with the Stack

Whenever you run a program which contains any function calls, `gawk` maintains a stack of all of the function calls leading up to where the program is right now. You can see how you got to where you are, and also move around in the stack to see what the state of things was in the functions which called the one you are in. The commands for doing this are:

`backtrace` [*count*]
`bt` [*count*]

Print a backtrace of all function calls (stack frames), or innermost *count* frames if *count* `>` 0. Print the outermost *count* frames if *count* `<` 0. The backtrace displays the name and arguments to each function, the source file name, and the line number.

`down` [*count*]
: Move *count* (default 1) frames down the stack toward the innermost frame. Then select and print the frame.

`frame` [*n*]
`f` [*n*]
: Select and print (frame number, function and argument names, source file, and the source line) stack frame *n*. Frame 0 is the currently executing, or *innermost*, frame (function call), frame 1 is the frame that called the innermost one. The highest numbered frame is the one for the main program.

`up` [*count*]
: Move *count* (default 1) frames up the stack toward the outermost frame. Then select and print the frame.

14.3.5 Obtaining Information about the Program and the Debugger State

Besides looking at the values of variables, there is often a need to get other sorts of information about the state of your program and of the debugging environment itself. The `gawk` debugger has one command which provides this information, appropriately called `info`. `info` is used with one of a number of arguments that tell it exactly what you want to know:

`info` *what*
`i` *what*
: The value for *what* should be one of the following:

  `args` Arguments of the selected frame.

  `break` List all currently set breakpoints.

  `display` List all items in the automatic display list.

  `frame` Description of the selected stack frame.

  `functions`
  List all function definitions including source file names and line numbers.

  `locals` Local variables of the selected frame.

  `source` The name of the current source file. Each time the program stops, the current source file is the file containing the current instruction. When the debugger first starts, the current source file is the first file included via the `-f` option. The '`list` *`filename`*`:`*`lineno`*' command can be used at any time to change the current source.

  `sources` List all program sources.

  `variables`
  List all global variables.

  `watch` List all items in the watch list.

Additional commands give you control over the debugger, the ability to save the debugger's state, and the ability to run debugger commands from a file. The commands are:

`option` [*name*[`=`*value*]]
`o` [*name*[`=`*value*]]

Without an argument, display the available debugger options and their current values. '`option` ***name***' shows the current value of the named option. '`option` ***name*=*value***' assigns a new value to the named option. The available options are:

`history_size`
The maximum number of lines to keep in the history file `./.gawk_history`. The default is 100.

`listsize` The number of lines that `list` prints. The default is 15.

`outfile` Send `gawk` output to a file; debugger output still goes to standard output. An empty string (`""`) resets output to standard output.

`prompt` The debugger prompt. The default is '`gawk> `'.

`save_history` [`on` | `off`]
Save command history to file `./.gawk_history`. The default is `on`.

`save_options` [`on` | `off`]
Save current options to file `./.gawkrc` upon exit. The default is `on`. Options are read back in to the next session upon startup.

`trace` [`on` | `off`]
Turn instruction tracing on or off. The default is `off`.

`save` *filename*
Save the commands from the current session to the given file name, so that they can be replayed using the `source` command.

`source` *filename*
Run command(s) from a file; an error in any command does not terminate execution of subsequent commands. Comments (lines starting with '`#`') are allowed in a command file. Empty lines are ignored; they do *not* repeat the last command. You can't restart the program by having more than one `run` command in the file. Also, the list of commands may include additional `source` commands; however, the `gawk` debugger will not source the same file more than once in order to avoid infinite recursion.

In addition to, or instead of the `source` command, you can use the `-D` ***file*** or `--debug=`***file*** command-line options to execute commands from a file non-interactively (see Section 2.2 [Command-Line Options], page 29).

14.3.6 Miscellaneous Commands

There are a few more commands which do not fit into the previous categories, as follows:

`dump` [*filename*]
Dump bytecode of the program to standard output or to the file named in *filename*. This prints a representation of the internal instructions which `gawk` executes to implement the `awk` commands in a program. This can be very enlightening, as the following partial dump of Davide Brini's obfuscated code

(see Section 11.3.11 [And Now For Something Completely Different], page 274) demonstrates:

```
gawk> dump
⊣   # BEGIN
⊣
⊣  [     1:0xfcd340] Op_rule             : [in_rule = BEGIN] [source_file = brini.awk]
⊣  [     1:0xfcc240] Op_push_i           : "~" [MALLOC|STRING|STRCUR]
⊣  [     1:0xfcc2a0] Op_push_i           : "~" [MALLOC|STRING|STRCUR]
⊣  [     1:0xfcc280] Op_match            :
⊣  [     1:0xfcc1e0] Op_store_var        : O
⊣  [     1:0xfcc2e0] Op_push_i           : "==" [MALLOC|STRING|STRCUR]
⊣  [     1:0xfcc340] Op_push_i           : "==" [MALLOC|STRING|STRCUR]
⊣  [     1:0xfcc320] Op_equal            :
⊣  [     1:0xfcc200] Op_store_var        : o
⊣  [     1:0xfcc380] Op_push             : o
⊣  [     1:0xfcc360] Op_plus_i           : 0 [MALLOC|NUMCUR|NUMBER]
⊣  [     1:0xfcc220] Op_push_lhs         : o [do_reference = true]
⊣  [     1:0xfcc300] Op_assign_plus      :
⊣  [      :0xfcc2c0] Op_pop              :
⊣  [     1:0xfcc400] Op_push             : O
⊣  [     1:0xfcc420] Op_push_i           : "" [MALLOC|STRING|STRCUR]
⊣  [      :0xfcc4a0] Op_no_op            :
⊣  [     1:0xfcc480] Op_push             : O
⊣  [      :0xfcc4c0] Op_concat           : [expr_count = 3] [concat_flag = 0]
⊣  [     1:0xfcc3c0] Op_store_var        : x
⊣  [     1:0xfcc440] Op_push_lhs         : X [do_reference = true]
⊣  [     1:0xfcc3a0] Op_postincrement    :
⊣  [     1:0xfcc4e0] Op_push             : x
⊣  [     1:0xfcc540] Op_push             : o
⊣  [     1:0xfcc500] Op_plus             :
⊣  [     1:0xfcc580] Op_push             : o
⊣  [     1:0xfcc560] Op_plus             :
⊣  [     1:0xfcc460] Op_leq              :
⊣  [      :0xfcc5c0] Op_jmp_false        : [target_jmp = 0xfcc5e0]
⊣  [     1:0xfcc600] Op_push_i           : "%c" [MALLOC|STRING|STRCUR]
⊣  [      :0xfcc660] Op_no_op            :
⊣  [     1:0xfcc520] Op_assign_concat    : c
⊣  [      :0xfcc620] Op_jmp              : [target_jmp = 0xfcc440]
⊣
...
⊣
⊣  [     2:0xfcc5a0] Op_K_printf         : [expr_count = 17] [redir_type = ""]
⊣  [      :0xfcc140] Op_no_op            :
⊣  [      :0xfcc1c0] Op_atexit           :
⊣  [      :0xfcc640] Op_stop             :
⊣  [      :0xfcc180] Op_no_op            :
⊣  [      :0xfcd150] Op_after_beginfile  :
⊣  [      :0xfcc160] Op_no_op            :
⊣  [      :0xfcc1a0] Op_after_endfile    :
gawk>
```

`help`
`h`
: Print a list of all of the `gawk` debugger commands with a short summary of their usage. '`help` *command*' prints the information about the command *command*.

`list` [`-` | `+` | *n* | *filename*`:`*n* | *n*–*m* | *function*]
`l` [`-` | `+` | *n* | *filename*`:`*n* | *n*–*m* | *function*]

Print the specified lines (default 15) from the current source file or the file named *filename*. The possible arguments to `list` are as follows:

`-` Print lines before the lines last printed.

`+` Print lines after the lines last printed. `list` without any argument does the same thing.

n Print lines centered around line number *n*.

n–*m* Print lines from *n* to *m*.

filename`:`*n*
Print lines centered around line number *n* in source file *filename*. This command may change the current source file.

function Print lines centered around beginning of the function *function*. This command may change the current source file.

`quit`
`q` Exit the debugger. Debugging is great fun, but sometimes we all have to tend to other obligations in life, and sometimes we find the bug, and are free to go on to the next one! As we saw above, if you are running a program, the debugger warns you if you accidentally type '`q`' or '`quit`', to make sure you really want to quit.

`trace on | off`
Turn on or off a continuous printing of instructions which are about to be executed, along with printing the `awk` line which they implement. The default is `off`.

It is to be hoped that most of the "opcodes" in these instructions are fairly self-explanatory, and using `stepi` and `nexti` while `trace` is on will make them into familiar friends.

14.4 Readline Support

If `gawk` is compiled with the `readline` library, you can take advantage of that library's command completion and history expansion features. The following types of completion are available:

Command completion
Command names.

Source file name completion
Source file names. Relevant commands are `break`, `clear`, `list`, `tbreak`, and `until`.

Argument completion
Non-numeric arguments to a command. Relevant commands are `enable` and `info`.

Variable name completion
: Global variable names, and function arguments in the current context if the program is running. Relevant commands are `display`, `print`, `set`, and `watch`.

14.5 Limitations and Future Plans

We hope you find the `gawk` debugger useful and enjoyable to work with, but as with any program, especially in its early releases, it still has some limitations. A few which are worth being aware of are:

- At this point, the debugger does not give a detailed explanation of what you did wrong when you type in something it doesn't like. Rather, it just responds '`syntax error`'. When you do figure out what your mistake was, though, you'll feel like a real guru.
- If you perused the dump of opcodes in Section 14.3.6 [Miscellaneous Commands], page 312, (or if you are already familiar with `gawk` internals), you will realize that much of the internal manipulation of data in `gawk`, as in many interpreters, is done on a stack. `Op_push`, `Op_pop`, etc., are the "bread and butter" of most `gawk` code. Unfortunately, as of now, the `gawk` debugger does not allow you to examine the stack's contents.

  That is, the intermediate results of expression evaluation are on the stack, but cannot be printed. Rather, only variables which are defined in the program can be printed. Of course, a workaround for this is to use more explicit variables at the debugging stage and then change back to obscure, perhaps more optimal code later.
- There is no way to look "inside" the process of compiling regular expressions to see if you got it right. As an `awk` programmer, you are expected to know what `/[^[:alnum:][:blank:]]/` means.
- The `gawk` debugger is designed to be used by running a program (with all its parameters) on the command line, as described in Section 14.2.1 [How to Start the Debugger], page 303. There is no way (as of now) to attach or "break in" to a running program. This seems reasonable for a language which is used mainly for quickly executing, short programs.
- The `gawk` debugger only accepts source supplied with the `-f` option.

Look forward to a future release when these and other missing features may be added, and of course feel free to try to add them yourself!

15 Arithmetic and Arbitrary Precision Arithmetic with gawk

> *There's a credibility gap: We don't know how much of the computer's answers to believe. Novice computer users solve this problem by implicitly trusting in the computer as an infallible authority; they tend to believe that all digits of a printed answer are significant. Disillusioned computer users have just the opposite approach; they are constantly afraid that their answers are almost meaningless.*
> Donald Knuth[1]

This chapter discusses issues that you may encounter when performing arithmetic. It begins by discussing some of the general attributes of computer arithmetic, along with how this can influence what you see when running `awk` programs. This discussion applies to all versions of `awk`.

The chapter then moves on to describe *arbitrary precision arithmetic*, a feature which is specific to `gawk`.

15.1 A General Description of Computer Arithmetic

Within computers, there are two kinds of numeric values: *integers* and *floating-point*. In school, integer values were referred to as "whole" numbers—that is, numbers without any fractional part, such as 1, 42, or −17. The advantage to integer numbers is that they represent values exactly. The disadvantage is that their range is limited. On most systems, this range is −2,147,483,648 to 2,147,483,647. However, many systems now support a range from −9,223,372,036,854,775,808 to 9,223,372,036,854,775,807.

Integer values come in two flavors: *signed* and *unsigned*. Signed values may be negative or positive, with the range of values just described. Unsigned values are always positive. On most systems, the range is from 0 to 4,294,967,295. However, many systems now support a range from 0 to 18,446,744,073,709,551,615.

Floating-point numbers represent what are called "real" numbers; i.e., those that do have a fractional part, such as 3.1415927. The advantage to floating-point numbers is that they can represent a much larger range of values. The disadvantage is that there are numbers that they cannot represent exactly. `awk` uses *double precision* floating-point numbers, which can hold more digits than *single precision* floating-point numbers.

There a several important issues to be aware of, described next.

15.1.1 Floating-Point Number Caveats

This section describes some of the issues involved in using floating-point numbers.

There is a very nice paper on floating-point arithmetic (`http://www.validlab.com/goldberg/paper.pdf`) by David Goldberg, "What Every Computer Scientist Should Know About Floating-point Arithmetic," *ACM Computing Surveys* **23**, 1 (1991-03), 5-48. This is worth reading if you are interested in the details, but it does require a background in computer science.

---

[1] Donald E. Knuth. *The Art of Computer Programming*. Volume 2, *Seminumerical Algorithms*, third edition, 1998, ISBN 0-201-89683-4, p. 229.

15.1.1.1 The String Value Can Lie

Internally, `awk` keeps both the numeric value (double precision floating-point) and the string value for a variable. Separately, `awk` keeps track of what type the variable has (see Section 6.3.2 [Variable Typing and Comparison Expressions], page 110), which plays a role in how variables are used in comparisons.

It is important to note that the string value for a number may not reflect the full value (all the digits) that the numeric value actually contains. The following program, `values.awk`, illustrates this:

```
{
   sum = $1 + $2
   # see it for what it is
   printf("sum = %.12g\n", sum)
   # use CONVFMT
   a = "<" sum ">"
   print "a =", a
   # use OFMT
   print "sum =", sum
}
```

This program shows the full value of the sum of `$1` and `$2` using `printf`, and then prints the string values obtained from both automatic conversion (via `CONVFMT`) and from printing (via `OFMT`).

Here is what happens when the program is run:

```
$ echo 3.654321 1.2345678 | awk -f values.awk
⊣ sum = 4.8888888
⊣ a = <4.88889>
⊣ sum = 4.88889
```

This makes it clear that the full numeric value is different from what the default string representations show.

`CONVFMT`'s default value is `"%.6g"`, which yields a value with at most six significant digits. For some applications, you might want to change it to specify more precision. On most modern machines, most of the time, 17 digits is enough to capture a floating-point number's value exactly.[2]

15.1.1.2 Floating Point Numbers Are Not Abstract Numbers

Unlike numbers in the abstract sense (such as what you studied in high school or college arithmetic), numbers stored in computers are limited in certain ways. They cannot represent an infinite number of digits, nor can they always represent things exactly. In particular, floating-point numbers cannot always represent values exactly. Here is an example:

```
$ awk '{ printf("%010d\n", $1 * 100) }'
515.79
⊣ 0000051579
515.80
⊣ 0000051579
```

---

[2] Pathological cases can require up to 752 digits (!), but we doubt that you need to worry about this.

```
515.81
⊣ 0000051580
515.82
⊣ 0000051582
Ctrl-d
```

This shows that some values can be represented exactly, whereas others are only approximated. This is not a "bug" in awk, but simply an artifact of how computers represent numbers.

> **NOTE:** It cannot be emphasized enough that the behavior just described is fundamental to modern computers. You will see this kind of thing happen in *any* programming language using hardware floating-point numbers. It is *not* a bug in gawk, nor is it something that can be "just fixed."

Another peculiarity of floating-point numbers on modern systems is that they often have more than one representation for the number zero! In particular, it is possible to represent "minus zero" as well as regular, or "positive" zero.

This example shows that negative and positive zero are distinct values when stored internally, but that they are in fact equal to each other, as well as to "regular" zero:

```
$ gawk 'BEGIN { mz = -0 ; pz = 0
> printf "-0 = %g, +0 = %g, (-0 == +0) -> %d\n", mz, pz, mz == pz
> printf "mz == 0 -> %d, pz == 0 -> %d\n", mz == 0, pz == 0
> }'
⊣ -0 = -0, +0 = 0, (-0 == +0) -> 1
⊣ mz == 0 -> 1, pz == 0 -> 1
```

It helps to keep this in mind should you process numeric data that contains negative zero values; the fact that the zero is negative is noted and can affect comparisons.

15.1.1.3 Standards Versus Existing Practice

Historically, awk has converted any non-numeric looking string to the numeric value zero, when required. Furthermore, the original definition of the language and the original POSIX standards specified that awk only understands decimal numbers (base 10), and not octal (base 8) or hexadecimal numbers (base 16).

Changes in the language of the 2001 and 2004 POSIX standards can be interpreted to imply that awk should support additional features. These features are:

- Interpretation of floating point data values specified in hexadecimal notation ('0xDEADBEEF'). (Note: data values, *not* source code constants.)
- Support for the special IEEE 754 floating point values "Not A Number" (NaN), positive Infinity ("inf") and negative Infinity ("−inf"). In particular, the format for these values is as specified by the ISO 1999 C standard, which ignores case and can allow machine-dependent additional characters after the 'nan' and allow either 'inf' or 'infinity'.

The first problem is that both of these are clear changes to historical practice:

- The gawk maintainer feels that supporting hexadecimal floating point values, in particular, is ugly, and was never intended by the original designers to be part of the language.

- Allowing completely alphabetic strings to have valid numeric values is also a very severe departure from historical practice.

The second problem is that the `gawk` maintainer feels that this interpretation of the standard, which requires a certain amount of "language lawyering" to arrive at in the first place, was not even intended by the standard developers. In other words, "we see how you got where you are, but we don't think that that's where you want to be."

Recognizing the above issues, but attempting to provide compatibility with the earlier versions of the standard, the 2008 POSIX standard added explicit wording to allow, but not require, that `awk` support hexadecimal floating point values and special values for "Not A Number" and infinity.

Although the `gawk` maintainer continues to feel that providing those features is inadvisable, nevertheless, on systems that support IEEE floating point, it seems reasonable to provide *some* way to support NaN and Infinity values. The solution implemented in `gawk` is as follows:

- With the `--posix` command-line option, `gawk` becomes "hands off." String values are passed directly to the system library's `strtod()` function, and if it successfully returns a numeric value, that is what's used.[3] By definition, the results are not portable across different systems. They are also a little surprising:

```
$ echo nanny | gawk --posix '{ print $1 + 0 }'
⊣ nan
$ echo 0xDeadBeef | gawk --posix '{ print $1 + 0 }'
⊣ 3735928559
```

- Without `--posix`, `gawk` interprets the four strings '`+inf`', '`-inf`', '`+nan`', and '`-nan`' specially, producing the corresponding special numeric values. The leading sign acts a signal to `gawk` (and the user) that the value is really numeric. Hexadecimal floating point is not supported (unless you also use `--non-decimal-data`, which is *not* recommended). For example:

```
$ echo nanny | gawk '{ print $1 + 0 }'
⊣ 0
$ echo +nan | gawk '{ print $1 + 0 }'
⊣ nan
$ echo 0xDeadBeef | gawk '{ print $1 + 0 }'
⊣ 0
```

`gawk` does ignore case in the four special values. Thus '`+nan`' and '`+NaN`' are the same.

15.1.2 Mixing Integers And Floating-point

As has been mentioned already, `awk` uses hardware double precision with 64-bit IEEE binary floating-point representation for numbers on most systems. A large integer like 9,007,199,254,740,997 has a binary representation that, although finite, is more than 53 bits long; it must also be rounded to 53 bits. The biggest integer that can be stored in a C `double` is usually the same as the largest possible value of a `double`. If your system `double` is an IEEE 64-bit `double`, this largest possible value is an integer and can be represented precisely. What more should one know about integers?

[3] You asked for it, you got it.

If you want to know what is the largest integer, such that it and all smaller integers can be stored in 64-bit doubles without losing precision, then the answer is 2^{53}. The next representable number is the even number $2^{53}+2$, meaning it is unlikely that you will be able to make `gawk` print $2^{53}+1$ in integer format. The range of integers exactly representable by a 64-bit double is $[-2^{53}, 2^{53}]$. If you ever see an integer outside this range in `awk` using 64-bit doubles, you have reason to be very suspicious about the accuracy of the output. Here is a simple program with erroneous output:

```
$ gawk 'BEGIN { i = 2^53 - 1; for (j = 0; j < 4; j++) print i + j }'
⊣ 9007199254740991
⊣ 9007199254740992
⊣ 9007199254740992
⊣ 9007199254740994
```

The lesson is to not assume that any large integer printed by `awk` represents an exact result from your computation, especially if it wraps around on your screen.

15.2 Understanding Floating-point Programming

Numerical programming is an extensive area; if you need to develop sophisticated numerical algorithms then `gawk` may not be the ideal tool, and this documentation may not be sufficient. It might require digesting a book or two[4] to really internalize how to compute with ideal accuracy and precision, and the result often depends on the particular application.

> **NOTE:** A floating-point calculation's *accuracy* is how close it comes to the real value. This is as opposed to the *precision*, which usually refers to the number of bits used to represent the number (see the Wikipedia article (`http://en.wikipedia.org/wiki/Accuracy_and_precision`) for more information).

There are two options for doing floating-point calculations: hardware floating-point (as used by standard `awk` and the default for `gawk`), and *arbitrary-precision* floating-point, which is software based. From this point forward, this chapter aims to provide enough information to understand both, and then will focus on `gawk`'s facilities for the latter.[5]

Binary floating-point representations and arithmetic are inexact. Simple values like 0.1 cannot be precisely represented using binary floating-point numbers, and the limited precision of floating-point numbers means that slight changes in the order of operations or the precision of intermediate storage can change the result. To make matters worse, with arbitrary precision floating-point, you can set the precision before starting a computation, but then you cannot be sure of the number of significant decimal places in the final result.

Sometimes, before you start to write any code, you should think more about what you really want and what's really happening. Consider the two numbers in the following example:

```
x = 0.875             # 1/2 + 1/4 + 1/8
y = 0.425
```

---

[4] One recommended title is *Numerical Computing with IEEE Floating Point Arithmetic*, Michael L. Overton, Society for Industrial and Applied Mathematics, 2004. ISBN: 0-89871-482-6, ISBN-13: 978-0-89871-482-1. See `http://www.cs.nyu.edu/cs/faculty/overton/book`.

[5] If you are interested in other tools that perform arbitrary precision arithmetic, you may want to investigate the POSIX `bc` tool. See the POSIX specification for it (`http://pubs.opengroup.org/onlinepubs/009695399/utilities/bc.html`), for more information.

Unlike the number in y, the number stored in x is exactly representable in binary since it can be written as a finite sum of one or more fractions whose denominators are all powers of two. When gawk reads a floating-point number from program source, it automatically rounds that number to whatever precision your machine supports. If you try to print the numeric content of a variable using an output format string of "%.17g", it may not produce the same number as you assigned to it:

```
$ gawk 'BEGIN { x = 0.875; y = 0.425
>               printf("%0.17g, %0.17g\n", x, y) }'
⊣ 0.875, 0.42499999999999999
```

Often the error is so small you do not even notice it, and if you do, you can always specify how much precision you would like in your output. Usually this is a format string like "%.15g", which when used in the previous example, produces an output identical to the input.

Because the underlying representation can be a little bit off from the exact value, comparing floating-point values to see if they are equal is generally not a good idea. Here is an example where it does not work like you expect:

```
$ gawk 'BEGIN { print (0.1 + 12.2 == 12.3) }'
⊣ 0
```

The loss of accuracy during a single computation with floating-point numbers usually isn't enough to worry about. However, if you compute a value which is the result of a sequence of floating point operations, the error can accumulate and greatly affect the computation itself. Here is an attempt to compute the value of the constant π using one of its many series representations:

```
BEGIN {
    x = 1.0 / sqrt(3.0)
    n = 6
    for (i = 1; i < 30; i++) {
        n = n * 2.0
        x = (sqrt(x * x + 1) - 1) / x
        printf("%.15f\n", n * x)
    }
}
```

When run, the early errors propagating through later computations cause the loop to terminate prematurely after an attempt to divide by zero.

```
$ gawk -f pi.awk
⊣ 3.215390309173475
⊣ 3.159659942097510
⊣ 3.146086215131467
⊣ 3.142714599645573
...
⊣ 3.224515243534819
⊣ 2.791117213058638
⊣ 0.000000000000000
error  gawk: pi.awk:6: fatal: division by zero attempted
```

Here is an additional example where the inaccuracies in internal representations yield an unexpected result:

```
$ gawk 'BEGIN {
>   for (d = 1.1; d <= 1.5; d += 0.1)    # loop five times (?)
>       i++
>   print i
> }'
⊣ 4
```

Can computation using arbitrary precision help with the previous examples? If you are impatient to know, see Section 15.4.5 [Exact Arithmetic with Floating-point Numbers], page 329.

Instead of arbitrary precision floating-point arithmetic, often all you need is an adjustment of your logic or a different order for the operations in your calculation. The stability and the accuracy of the computation of the constant π in the earlier example can be enhanced by using the following simple algebraic transformation:

```
(sqrt(x * x + 1) - 1) / x = x / (sqrt(x * x + 1) + 1)
```

After making this, change the program does converge to π in under 30 iterations:

```
$ gawk -f pi2.awk
⊣ 3.215390309173473
⊣ 3.159659942097501
⊣ 3.146086215131436
⊣ 3.142714599645370
⊣ 3.141873049979825
...
⊣ 3.141592653589797
⊣ 3.141592653589797
```

There is no need to be unduly suspicious about the results from floating-point arithmetic. The lesson to remember is that floating-point arithmetic is always more complex than arithmetic using pencil and paper. In order to take advantage of the power of computer floating-point, you need to know its limitations and work within them. For most casual use of floating-point arithmetic, you will often get the expected result in the end if you simply round the display of your final results to the correct number of significant decimal digits.

As general advice, avoid presenting numerical data in a manner that implies better precision than is actually the case.

15.2.1 Binary Floating-point Representation

Although floating-point representations vary from machine to machine, the most commonly encountered representation is that defined by the IEEE 754 Standard. An IEEE-754 format value has three components:

- A sign bit telling whether the number is positive or negative.
- An *exponent*, e, giving its order of magnitude.
- A *significand*, s, specifying the actual digits of the number.

The value of the number is then $s \cdot 2^e$. The first bit of a non-zero binary significand is always one, so the significand in an IEEE-754 format only includes the fractional part, leaving the leading one implicit. The significand is stored in *normalized* format, which means that the first bit is always a one.

Three of the standard IEEE-754 types are 32-bit single precision, 64-bit double precision and 128-bit quadruple precision. The standard also specifies extended precision formats to allow greater precisions and larger exponent ranges.

15.2.2 Floating-point Context

A floating-point *context* defines the environment for arithmetic operations. It governs precision, sets rules for rounding, and limits the range for exponents. The context has the following primary components:

Precision Precision of the floating-point format in bits.

emax Maximum exponent allowed for the format.

emin Minimum exponent allowed for the format.

Underflow behavior
The format may or may not support gradual underflow.

Rounding The rounding mode of the context.

Table 15.1 lists the precision and exponent field values for the basic IEEE-754 binary formats:

Name	**Total bits**	**Precision**	**emin**	**emax**
Single	32	24	−126	+127
Double	64	53	−1022	+1023
Quadruple	128	113	−16382	+16383

Table 15.1: Basic IEEE Format Context Values

> **NOTE:** The precision numbers include the implied leading one that gives them one extra bit of significand.

A floating-point context can also determine which signals are treated as exceptions, and can set rules for arithmetic with special values. Please consult the IEEE-754 standard or other resources for details.

`gawk` ordinarily uses the hardware double precision representation for numbers. On most systems, this is IEEE-754 floating-point format, corresponding to 64-bit binary with 53 bits of precision.

> **NOTE:** In case an underflow occurs, the standard allows, but does not require, the result from an arithmetic operation to be a number smaller than the smallest nonzero normalized number. Such numbers do not have as many significant digits as normal numbers, and are called *denormals* or *subnormals*. The alternative, simply returning a zero, is called *flush to zero*. The basic IEEE-754 binary formats support subnormal numbers.

15.2.3 Floating-point Rounding Mode

The *rounding mode* specifies the behavior for the results of numerical operations when discarding extra precision. Each rounding mode indicates how the least significant returned digit of a rounded result is to be calculated. Table 15.2 lists the IEEE-754 defined rounding modes:

Rounding Mode	**IEEE Name**
Round to nearest, ties to even	`roundTiesToEven`
Round toward plus Infinity	`roundTowardPositive`
Round toward negative Infinity	`roundTowardNegative`
Round toward zero	`roundTowardZero`
Round to nearest, ties away from zero	`roundTiesToAway`

Table 15.2: IEEE 754 Rounding Modes

The default mode `roundTiesToEven` is the most preferred, but the least intuitive. This method does the obvious thing for most values, by rounding them up or down to the nearest digit. For example, rounding 1.132 to two digits yields 1.13, and rounding 1.157 yields 1.16.

However, when it comes to rounding a value that is exactly halfway between, things do not work the way you probably learned in school. In this case, the number is rounded to the nearest even digit. So rounding 0.125 to two digits rounds down to 0.12, but rounding 0.6875 to three digits rounds up to 0.688. You probably have already encountered this rounding mode when using `printf` to format floating-point numbers. For example:

```
BEGIN {
    x = -4.5
    for (i = 1; i < 10; i++) {
        x += 1.0
        printf("%4.1f => %2.0f\n", x, x)
    }
}
```

produces the following output when run on the author's system:[6]

```
-3.5 => -4
-2.5 => -2
-1.5 => -2
-0.5 => 0
 0.5 => 0
 1.5 => 2
 2.5 => 2
 3.5 => 4
 4.5 => 4
```

The theory behind the rounding mode `roundTiesToEven` is that it more or less evenly distributes upward and downward rounds of exact halves, which might cause any round-off error to cancel itself out. This is the default rounding mode used in IEEE-754 computing functions and operators.

The other rounding modes are rarely used. Round toward positive infinity (`roundTowardPositive`) and round toward negative infinity (`roundTowardNegative`)

[6] It is possible for the output to be completely different if the C library in your system does not use the IEEE-754 even-rounding rule to round halfway cases for `printf`.

are often used to implement interval arithmetic, where you adjust the rounding mode to calculate upper and lower bounds for the range of output. The `roundTowardZero` mode can be used for converting floating-point numbers to integers. The rounding mode `roundTiesToAway` rounds the result to the nearest number and selects the number with the larger magnitude if a tie occurs.

Some numerical analysts will tell you that your choice of rounding style has tremendous impact on the final outcome, and advise you to wait until final output for any rounding. Instead, you can often avoid round-off error problems by setting the precision initially to some value sufficiently larger than the final desired precision, so that the accumulation of round-off error does not influence the outcome. If you suspect that results from your computation are sensitive to accumulation of round-off error, one way to be sure is to look for a significant difference in output when you change the rounding mode.

15.3 gawk + MPFR = Powerful Arithmetic

The rest of this chapter describes how to use the arbitrary precision (also known as *multiple precision* or *infinite precision*) numeric capabilities in `gawk` to produce maximally accurate results when you need it.

But first you should check if your version of `gawk` supports arbitrary precision arithmetic. The easiest way to find out is to look at the output of the following command:

```
$ gawk --version
⊣ GNU Awk 4.1.0, API: 1.0 (GNU MPFR 3.1.0-p3, GNU MP 5.0.2)
⊣ Copyright (C) 1989, 1991-2013 Free Software Foundation.
...
```

`gawk` uses the GNU MPFR (`http://www.mpfr.org`) and GNU MP (`http://gmplib.org`) (GMP) libraries for arbitrary precision arithmetic on numbers. So if you do not see the names of these libraries in the output, then your version of `gawk` does not support arbitrary precision arithmetic.

Additionally, there are a few elements available in the `PROCINFO` array to provide information about the MPFR and GMP libraries. See Section 7.5.2 [Built-in Variables That Convey Information], page 137, for more information.

15.4 Arbitrary Precision Floating-point Arithmetic with gawk

`gawk` uses the GNU MPFR library for arbitrary precision floating-point arithmetic. The MPFR library provides precise control over precisions and rounding modes, and gives correctly rounded, reproducible, platform-independent results. With one of the command-line options `--bignum` or `-M`, all floating-point arithmetic operators and numeric functions can yield results to any desired precision level supported by MPFR. Two built-in variables, `PREC` and `ROUNDMODE`, provide control over the working precision and the rounding mode (see Section 15.4.1 [Setting the Working Precision], page 327, and see Section 15.4.2 [Setting the Rounding Mode], page 328). The precision and the rounding mode are set globally for every operation to follow.

The default working precision for arbitrary precision floating-point values is 53 bits, and the default value for `ROUNDMODE` is `"N"`, which selects the IEEE-754 `roundTiesToEven` rounding mode (see Section 15.2.3 [Floating-point Rounding Mode], page 324).[7] gawk uses the default exponent range in MPFR ($emax = 2^{30} - 1, emin = -emax$) for all floating-point contexts. There is no explicit mechanism to adjust the exponent range. MPFR does not implement subnormal numbers by default, and this behavior cannot be changed in gawk.

> **NOTE:** When emulating an IEEE-754 format (see Section 15.4.1 [Setting the Working Precision], page 327), gawk internally adjusts the exponent range to the value defined for the format and also performs computations needed for gradual underflow (subnormal numbers).

> **NOTE:** MPFR numbers are variable-size entities, consuming only as much space as needed to store the significant digits. Since the performance using MPFR numbers pales in comparison to doing arithmetic using the underlying machine types, you should consider using only as much precision as needed by your program.

15.4.1 Setting the Working Precision

gawk uses a global working precision; it does not keep track of the precision or accuracy of individual numbers. Performing an arithmetic operation or calling a built-in function rounds the result to the current working precision. The default working precision is 53 bits, which can be modified using the built-in variable PREC. You can also set the value to one of the pre-defined case-insensitive strings shown in Table 15.3, to emulate an IEEE-754 binary format.

PREC	**IEEE-754 Binary Format**
"half"	16-bit half-precision.
"single"	Basic 32-bit single precision.
"double"	Basic 64-bit double precision.
"quad"	Basic 128-bit quadruple precision.
"oct"	256-bit octuple precision.

Table 15.3: Predefined precision strings for PREC

The following example illustrates the effects of changing precision on arithmetic operations:

```
$ gawk -M -v PREC=100 'BEGIN { x = 1.0e-400; print x + 0
>   PREC = "double"; print x + 0 }'
⊣ 1e-400
⊣ 0
```

Binary and decimal precisions are related approximately, according to the formula:

$prec = 3.322 \cdot dps$

Here, *prec* denotes the binary precision (measured in bits) and *dps* (short for decimal places) is the decimal digits. We can easily calculate how many decimal digits the 53-bit significand of an IEEE double is equivalent to: 53 / 3.322 which is equal to about 15.95. But what

[7] The default precision is 53 bits, since according to the MPFR documentation, the library should be able to exactly reproduce all computations with double-precision machine floating-point numbers (double type in C), except the default exponent range is much wider and subnormal numbers are not implemented.

does 15.95 digits actually mean? It depends whether you are concerned about how many digits you can rely on, or how many digits you need.

It is important to know how many bits it takes to uniquely identify a double-precision value (the C type `double`). If you want to convert from `double` to decimal and back to `double` (e.g., saving a `double` representing an intermediate result to a file, and later reading it back to restart the computation), then a few more decimal digits are required. 17 digits is generally enough for a `double`.

It can also be important to know what decimal numbers can be uniquely represented with a `double`. If you want to convert from decimal to `double` and back again, 15 digits is the most that you can get. Stated differently, you should not present the numbers from your floating-point computations with more than 15 significant digits in them.

Conversely, it takes a precision of 332 bits to hold an approximation of the constant π that is accurate to 100 decimal places.

You should always add some extra bits in order to avoid the confusing round-off issues that occur because numbers are stored internally in binary.

15.4.2 Setting the Rounding Mode

The `ROUNDMODE` variable provides program level control over the rounding mode. The correspondence between `ROUNDMODE` and the IEEE rounding modes is shown in Table 15.4.

Rounding Mode	**IEEE Name**	`ROUNDMODE`
Round to nearest, ties to even	`roundTiesToEven`	`"N"` or `"n"`
Round toward plus Infinity	`roundTowardPositive`	`"U"` or `"u"`
Round toward negative Infinity	`roundTowardNegative`	`"D"` or `"d"`
Round toward zero	`roundTowardZero`	`"Z"` or `"z"`
Round to nearest, ties away from zero	`roundTiesToAway`	`"A"` or `"a"`

Table 15.4: `gawk` Rounding Modes

`ROUNDMODE` has the default value `"N"`, which selects the IEEE-754 rounding mode `roundTiesToEven`. In Table 15.4, `"A"` is listed to select the IEEE-754 mode `roundTiesToAway`. This is only available if your version of the MPFR library supports it; otherwise setting `ROUNDMODE` to this value has no effect. See Section 15.2.3 [Floating-point Rounding Mode], page 324, for the meanings of the various rounding modes.

Here is an example of how to change the default rounding behavior of `printf`'s output:

```
$ gawk -M -v ROUNDMODE="Z" 'BEGIN { printf("%.2f\n", 1.378) }'
⊣ 1.37
```

15.4.3 Representing Floating-point Constants

Be wary of floating-point constants! When reading a floating-point constant from program source code, `gawk` uses the default precision, unless overridden by an assignment to the special variable `PREC` on the command line, to store it internally as a MPFR number. Changing the precision using `PREC` in the program text does *not* change the precision of a constant. If you need to represent a floating-point constant at a higher precision than the default and cannot use a command line assignment to `PREC`, you should either specify the constant as a string, or as a rational number, whenever possible. The following example illustrates the differences among various ways to print a floating-point constant:

```
$ gawk -M 'BEGIN { PREC = 113; printf("%0.25f\n", 0.1) }'
⊣ 0.1000000000000000055511151
$ gawk -M -v PREC=113 'BEGIN { printf("%0.25f\n", 0.1) }'
⊣ 0.1000000000000000000000000
$ gawk -M 'BEGIN { PREC = 113; printf("%0.25f\n", "0.1") }'
⊣ 0.1000000000000000000000000
$ gawk -M 'BEGIN { PREC = 113; printf("%0.25f\n", 1/10) }'
⊣ 0.1000000000000000000000000
```

In the first case, the number is stored with the default precision of 53 bits.

15.4.4 Changing the Precision of a Number

The point is that in any variable-precision package, a decision is made on how to treat numbers given as data, or arising in intermediate results, which are represented in floating-point format to a precision lower than working precision. Do we promote them to full membership of the high-precision club, or do we treat them and all their associates as second-class citizens? Sometimes the first course is proper, sometimes the second, and it takes careful analysis to tell which.

Dirk Laurie[8]

gawk does not implicitly modify the precision of any previously computed results when the working precision is changed with an assignment to PREC. The precision of a number is always the one that was used at the time of its creation, and there is no way for the user to explicitly change it afterwards. However, since the result of a floating-point arithmetic operation is always an arbitrary precision floating-point value—with a precision set by the value of PREC—one of the following workarounds effectively accomplishes the desired behavior:

```
x = x + 0.0
```

or:

```
x += 0.0
```

15.4.5 Exact Arithmetic with Floating-point Numbers

CAUTION: Never depend on the exactness of floating-point arithmetic, even for apparently simple expressions!

Can arbitrary precision arithmetic give exact results? There are no easy answers. The standard rules of algebra often do not apply when using floating-point arithmetic. Among other things, the distributive and associative laws do not hold completely, and order of operation may be important for your computation. Rounding error, cumulative precision loss and underflow are often troublesome.

When gawk tests the expressions '0.1 + 12.2' and '12.3' for equality using the machine double precision arithmetic, it decides that they are not equal! (See Section 15.2 [Under-

[8] Dirk Laurie. *Variable-precision Arithmetic Considered Perilous — A Detective Story*. Electronic Transactions on Numerical Analysis. Volume 28, pp. 168-173, 2008.

standing Floating-point Programming], page 321.) You can get the result you want by increasing the precision; 56 bits in this case will get the job done:

```
$ gawk -M -v PREC=56 'BEGIN { print (0.1 + 12.2 == 12.3) }'
⊣ 1
```

If adding more bits is good, perhaps adding even more bits of precision is better? Here is what happens if we use an even larger value of PREC:

```
$ gawk -M -v PREC=201 'BEGIN { print (0.1 + 12.2 == 12.3) }'
⊣ 0
```

This is not a bug in gawk or in the MPFR library. It is easy to forget that the finite number of bits used to store the value is often just an approximation after proper rounding. The test for equality succeeds if and only if *all* bits in the two operands are exactly the same. Since this is not necessarily true after floating-point computations with a particular precision and effective rounding rule, a straight test for equality may not work.

So, don't assume that floating-point values can be compared for equality. You should also exercise caution when using other forms of comparisons. The standard way to compare between floating-point numbers is to determine how much error (or *tolerance*) you will allow in a comparison and check to see if one value is within this error range of the other.

In applications where 15 or fewer decimal places suffice, hardware double precision arithmetic can be adequate, and is usually much faster. But you do need to keep in mind that every floating-point operation can suffer a new rounding error with catastrophic consequences as illustrated by our earlier attempt to compute the value of the constant π (see Section 15.2 [Understanding Floating-point Programming], page 321). Extra precision can greatly enhance the stability and the accuracy of your computation in such cases.

Repeated addition is not necessarily equivalent to multiplication in floating-point arithmetic. In the example in Section 15.2 [Understanding Floating-point Programming], page 321:

```
$ gawk 'BEGIN {
>   for (d = 1.1; d <= 1.5; d += 0.1)    # loop five times (?)
>       i++
>   print i
> }'
⊣ 4
```

you may or may not succeed in getting the correct result by choosing an arbitrarily large value for PREC. Reformulation of the problem at hand is often the correct approach in such situations.

15.5 Arbitrary Precision Integer Arithmetic with gawk

If one of the options --bignum or -M is specified, gawk performs all integer arithmetic using GMP arbitrary precision integers. Any number that looks like an integer in a program source or data file is stored as an arbitrary precision integer. The size of the integer is limited only by your computer's memory. The current floating-point context has no effect on operations involving integers. For example, the following computes $5^{4^{3^2}}$, the result of which is beyond the limits of ordinary gawk numbers:

```
$ gawk -M 'BEGIN {
>   x = 5^4^3^2
>   print "# of digits =", length(x)
>   print substr(x, 1, 20), "...", substr(x, length(x) - 19, 20)
> }'
⊣ # of digits = 183231
⊣ 62060698786608744707 ... 92256259918212890625
```

If you were to compute the same value using arbitrary precision floating-point values instead, the precision needed for correct output (using the formula $prec = 3.322 \cdot dps$), would be $3.322 \cdot 183231$, or 608693.

The result from an arithmetic operation with an integer and a floating-point value is a floating-point value with a precision equal to the working precision. The following program calculates the eighth term in Sylvester's sequence[9] using a recurrence:

```
$ gawk -M 'BEGIN {
>   s = 2.0
>   for (i = 1; i <= 7; i++)
>       s = s * (s - 1) + 1
>   print s
> }'
⊣ 113423713055421845118910464
```

The output differs from the actual number, 113,423,713,055,421,844,361,000,443, because the default precision of 53 bits is not enough to represent the floating-point results exactly. You can either increase the precision (100 bits is enough in this case), or replace the floating-point constant '2.0' with an integer, to perform all computations using integer arithmetic to get the correct output.

It will sometimes be necessary for gawk to implicitly convert an arbitrary precision integer into an arbitrary precision floating-point value. This is primarily because the MPFR library does not always provide the relevant interface to process arbitrary precision integers or mixed-mode numbers as needed by an operation or function. In such a case, the precision is set to the minimum value necessary for exact conversion, and the working precision is not used for this purpose. If this is not what you need or want, you can employ a subterfuge like this:

```
gawk -M 'BEGIN { n = 13; print (n + 0.0) % 2.0 }'
```

You can avoid this issue altogether by specifying the number as a floating-point value to begin with:

```
gawk -M 'BEGIN { n = 13.0; print n % 2.0 }'
```

Note that for the particular example above, there is likely best to just use the following:

```
gawk -M 'BEGIN { n = 13; print n % 2 }'
```

---

[9] Weisstein, Eric W. *Sylvester's Sequence*. From MathWorld—A Wolfram Web Resource. http://mathworld.wolfram.com/SylvestersSequence.html

16 Writing Extensions for gawk

It is possible to add new functions written in C or C++ to gawk using dynamically loaded libraries. This facility is available on systems that support the C dlopen() and dlsym() functions. This chapter describes how to create extensions using code written in C or C++.

If you don't know anything about C programming, you can safely skip this chapter, although you may wish to review the documentation on the extensions that come with gawk (see Section 16.7 [The Sample Extensions In The gawk Distribution], page 375), and the information on the gawkextlib project (see Section 16.8 [The gawkextlib Project], page 384). The sample extensions are automatically built and installed when gawk is.

> **NOTE:** When --sandbox is specified, extensions are disabled (see Section 2.2 [Command-Line Options], page 29).

16.1 Introduction

An *extension* (sometimes called a *plug-in*) is a piece of external compiled code that gawk can load at runtime to provide additional functionality, over and above the built-in capabilities described in the rest of this book.

Extensions are useful because they allow you (of course) to extend gawk's functionality. For example, they can provide access to system calls (such as chdir() to change directory) and to other C library routines that could be of use. As with most software, "the sky is the limit;" if you can imagine something that you might want to do and can write in C or C++, you can write an extension to do it!

Extensions are written in C or C++, using the *Application Programming Interface* (API) defined for this purpose by the gawk developers. The rest of this chapter explains the facilities that the API provides and how to use them, and presents a small sample extension. In addition, it documents the sample extensions included in the gawk distribution, and describes the gawkextlib project. See Section C.5 [Extension API Design], page 421, for a discussion of the extension mechanism goals and design.

16.2 Extension Licensing

Every dynamic extension should define the global symbol plugin_is_GPL_compatible to assert that it has been licensed under a GPL-compatible license. If this symbol does not exist, gawk emits a fatal error and exits when it tries to load your extension.

The declared type of the symbol should be int. It does not need to be in any allocated section, though. The code merely asserts that the symbol exists in the global scope. Something like this is enough:

```
int plugin_is_GPL_compatible;
```

16.3 At A High Level How It Works

Communication between gawk and an extension is two-way. First, when an extension is loaded, it is passed a pointer to a struct whose fields are function pointers. This is shown in Figure 16.1.

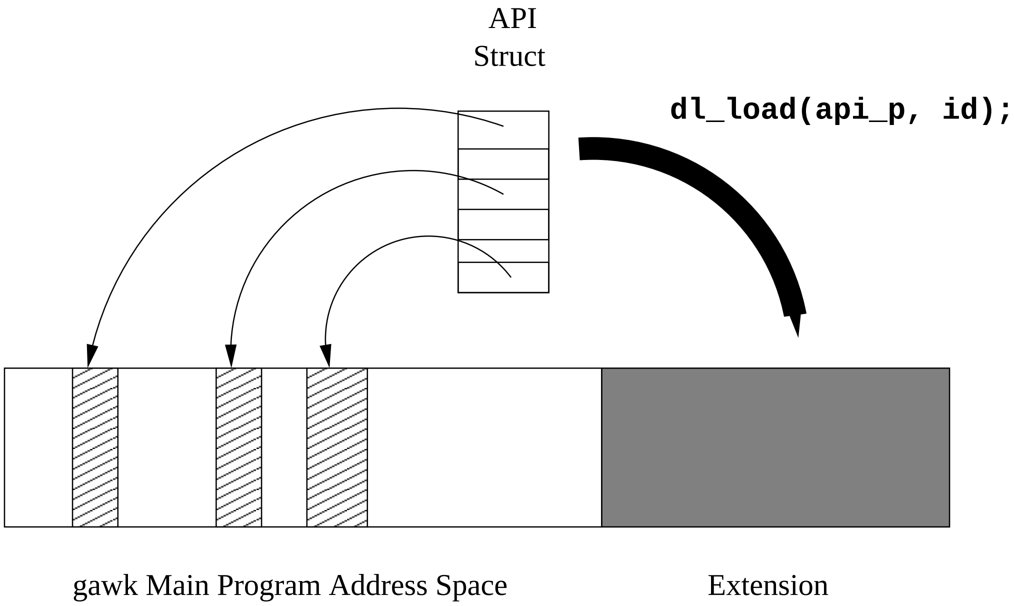

Figure 16.1: Loading The Extension

The extension can call functions inside `gawk` through these function pointers, at runtime, without needing (link-time) access to `gawk`'s symbols. One of these function pointers is to a function for "registering" new built-in functions. This is shown in Figure 16.2.

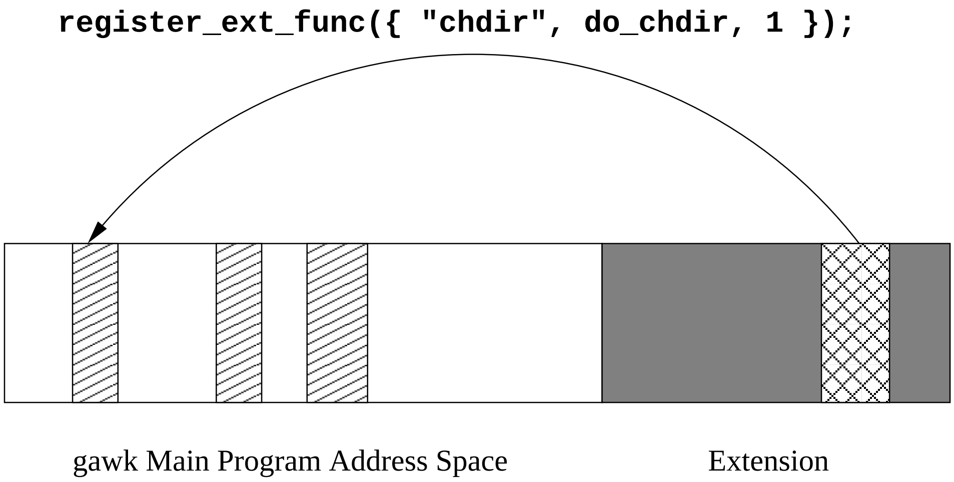

Figure 16.2: Loading The New Function

In the other direction, the extension registers its new functions with `gawk` by passing function pointers to the functions that provide the new feature (`do_chdir()`, for example). `gawk` associates the function pointer with a name and can then call it, using a defined calling convention. This is shown in Figure 16.3.

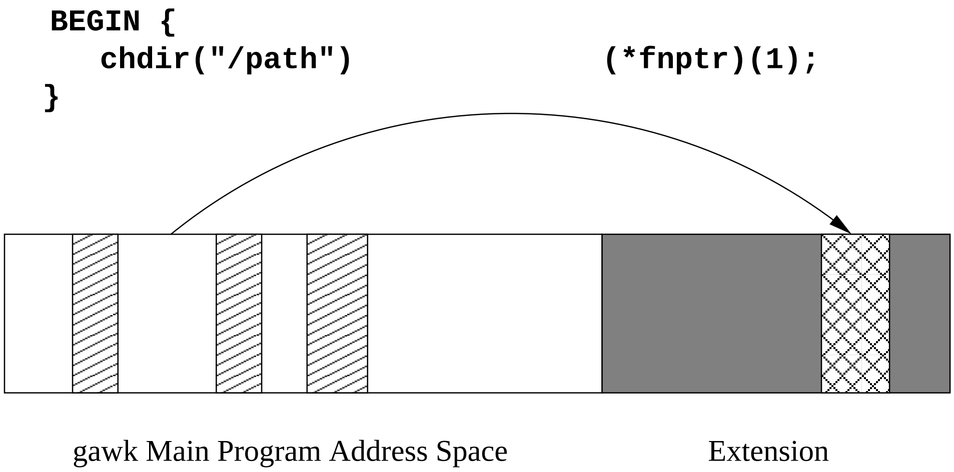

Figure 16.3: Calling The New Function

The `do_xxx()` function, in turn, then uses the function pointers in the API `struct` to do its work, such as updating variables or arrays, printing messages, setting `ERRNO`, and so on.

Convenience macros in the `gawkapi.h` header file make calling through the function pointers look like regular function calls so that extension code is quite readable and understandable.

Although all of this sounds somewhat complicated, the result is that extension code is quite straightforward to write and to read. You can see this in the sample extensions `filefuncs.c` (see Section 16.6 [Example: Some File Functions], page 365) and also the `testext.c` code for testing the APIs.

Some other bits and pieces:

- The API provides access to `gawk`'s `do_xxx` values, reflecting command line options, like `do_lint`, `do_profiling` and so on (see Section 16.4.11 [API Variables], page 362). These are informational: an extension cannot affect their values inside `gawk`. In addition, attempting to assign to them produces a compile-time error.
- The API also provides major and minor version numbers, so that an extension can check if the `gawk` it is loaded with supports the facilities it was compiled with. (Version mismatches "shouldn't" happen, but we all know how *that* goes.) See Section 16.4.11.1 [API Version Constants and Variables], page 362, for details.

16.4 API Description

This (rather large) section describes the API in detail.

16.4.1 Introduction

Access to facilities within `gawk` are made available by calling through function pointers passed into your extension.

API function pointers are provided for the following kinds of operations:

- Registrations functions. You may register:
  - extension functions,
  - exit callbacks,
  - a version string,
  - input parsers,
  - output wrappers,
  - and two-way processors.

  All of these are discussed in detail, later in this chapter.
- Printing fatal, warning, and “lint” warning messages.
- Updating `ERRNO`, or unsetting it.
- Accessing parameters, including converting an undefined parameter into an array.
- Symbol table access: retrieving a global variable, creating one, or changing one.
- Creating and releasing cached values; this provides an efficient way to use values for multiple variables and can be a big performance win.
- Manipulating arrays:
  - Retrieving, adding, deleting, and modifying elements
  - Getting the count of elements in an array
  - Creating a new array
  - Clearing an array
  - Flattening an array for easy C style looping over all its indices and elements

Some points about using the API:

- The following types and/or macros and/or functions are referenced in `gawkapi.h`. For correct use, you must therefore include the corresponding standard header file *before* including `gawkapi.h`:

C Entity	**Header File**
`EOF`	`<stdio.h>`
`FILE`	`<stdio.h>`
`NULL`	`<stddef.h>`
`malloc()`	`<stdlib.h>`
`memcpy()`	`<string.h>`
`memset()`	`<string.h>`
`realloc()`	`<stdlib.h>`
`size_t`	`<sys/types.h>`
`struct stat`	`<sys/stat.h>`

  Due to portability concerns, especially to systems that are not fully standards-compliant, it is your responsibility to include the correct files in the correct way. This requirement is necessary in order to keep `gawkapi.h` clean, instead of becoming a portability hodge-podge as can be seen in some parts of the `gawk` source code.

  To pass reasonable integer values for `ERRNO`, you will also need to include `<errno.h>`.
- The `gawkapi.h` file may be included more than once without ill effect. Doing so, however, is poor coding practice.

- Although the API only uses ISO C 90 features, there is an exception; the "constructor" functions use the `inline` keyword. If your compiler does not support this keyword, you should either place '`-Dinline=''`' on your command line, or use the GNU Autotools and include a `config.h` file in your extensions.
- All pointers filled in by `gawk` are to memory managed by `gawk` and should be treated by the extension as read-only. Memory for *all* strings passed into `gawk` from the extension *must* come from `malloc()` and is managed by `gawk` from then on.
- The API defines several simple `struct`s that map values as seen from `awk`. A value can be a `double`, a string, or an array (as in multidimensional arrays, or when creating a new array). String values maintain both pointer and length since embedded `NUL` characters are allowed.

    NOTE: By intent, strings are maintained using the current multibyte encoding (as defined by `LC_xxx` environment variables) and not using wide characters. This matches how `gawk` stores strings internally and also how characters are likely to be input and output from files.

- When retrieving a value (such as a parameter or that of a global variable or array element), the extension requests a specific type (number, string, scalars, value cookie, array, or "undefined"). When the request is "undefined," the returned value will have the real underlying type.

    However, if the request and actual type don't match, the access function returns "false" and fills in the type of the actual value that is there, so that the extension can, e.g., print an error message (such as "scalar passed where array expected").

While you may call the API functions by using the function pointers directly, the interface is not so pretty. To make extension code look more like regular code, the `gawkapi.h` header file defines several macros that you should use in your code. This section presents the macros as if they were functions.

16.4.2 General Purpose Data Types

> *I have a true love/hate relationship with unions.*
> Arnold Robbins
>
> *That's the thing about unions: the compiler will arrange things so they can accommodate both love and hate.*
> Chet Ramey

The extension API defines a number of simple types and structures for general purpose use. Additional, more specialized, data structures are introduced in subsequent sections, together with the functions that use them.

`typedef void *awk_ext_id_t;`

: A value of this type is received from `gawk` when an extension is loaded. That value must then be passed back to `gawk` as the first parameter of each API function.

`#define awk_const ...`

: This macro expands to '`const`' when compiling an extension, and to nothing when compiling `gawk` itself. This makes certain fields in the API data structures unwritable from extension code, while allowing `gawk` to use them as it needs to.

```
typedef enum awk_bool {
    awk_false = 0,
    awk_true
} awk_bool_t;
```

A simple boolean type.

```
typedef struct awk_string {
    char *str;       /* data */
    size_t len;      /* length thereof, in chars */
} awk_string_t;
```

This represents a mutable string. `gawk` owns the memory pointed to if it supplied the value. Otherwise, it takes ownership of the memory pointed to. **Such memory must come from `malloc()`!**

As mentioned earlier, strings are maintained using the current multibyte encoding.

```
typedef enum {
    AWK_UNDEFINED,
    AWK_NUMBER,
    AWK_STRING,
    AWK_ARRAY,
    AWK_SCALAR,         /* opaque access to a variable */
    AWK_VALUE_COOKIE    /* for updating a previously created value */
} awk_valtype_t;
```

This `enum` indicates the type of a value. It is used in the following `struct`.

```
typedef struct awk_value {
    awk_valtype_t val_type;
    union {
        awk_string_t       s;
        double             d;
        awk_array_t        a;
        awk_scalar_t       scl;
        awk_value_cookie_t vc;
    } u;
} awk_value_t;
```

An "`awk` value." The `val_type` member indicates what kind of value the `union` holds, and each member is of the appropriate type.

```
#define str_value      u.s
#define num_value      u.d
#define array_cookie   u.a
#define scalar_cookie  u.scl
#define value_cookie   u.vc
```

These macros make accessing the fields of the `awk_value_t` more readable.

```
typedef void *awk_scalar_t;
```

Scalars can be represented as an opaque type. These values are obtained from `gawk` and then passed back into it. This is discussed in a general fashion below, and in more detail in Section 16.4.9.2 [Variable Access and Update by Cookie], page 350.

`typedef void *awk_value_cookie_t;`
A "value cookie" is an opaque type representing a cached value. This is also discussed in a general fashion below, and in more detail in Section 16.4.9.3 [Creating and Using Cached Values], page 352.

Scalar values in `awk` are either numbers or strings. The `awk_value_t` struct represents values. The `val_type` member indicates what is in the `union`.

Representing numbers is easy—the API uses a C `double`. Strings require more work. Since `gawk` allows embedded `NUL` bytes in string values, a string must be represented as a pair containing a data-pointer and length. This is the `awk_string_t` type.

Identifiers (i.e., the names of global variables) can be associated with either scalar values or with arrays. In addition, `gawk` provides true arrays of arrays, where any given array element can itself be an array. Discussion of arrays is delayed until Section 16.4.10 [Array Manipulation], page 354.

The various macros listed earlier make it easier to use the elements of the `union` as if they were fields in a `struct`; this is a common coding practice in C. Such code is easier to write and to read, however it remains *your* responsibility to make sure that the `val_type` member correctly reflects the type of the value in the `awk_value_t`.

Conceptually, the first three members of the `union` (number, string, and array) are all that is needed for working with `awk` values. However, since the API provides routines for accessing and changing the value of global scalar variables only by using the variable's name, there is a performance penalty: `gawk` must find the variable each time it is accessed and changed. This turns out to be a real issue, not just a theoretical one.

Thus, if you know that your extension will spend considerable time reading and/or changing the value of one or more scalar variables, you can obtain a *scalar cookie*[1] object for that variable, and then use the cookie for getting the variable's value or for changing the variable's value. This is the `awk_scalar_t` type and `scalar_cookie` macro. Given a scalar cookie, `gawk` can directly retrieve or modify the value, as required, without having to first find it.

The `awk_value_cookie_t` type and `value_cookie` macro are similar. If you know that you wish to use the same numeric or string *value* for one or more variables, you can create the value once, retaining a *value cookie* for it, and then pass in that value cookie whenever you wish to set the value of a variable. This saves both storage space within the running `gawk` process as well as the time needed to create the value.

16.4.3 Requesting Values

All of the functions that return values from `gawk` work in the same way. You pass in an `awk_valtype_t` value to indicate what kind of value you expect. If the actual value matches what you requested, the function returns true and fills in the `awk_value_t` result. Otherwise, the function returns false, and the `val_type` member indicates the type of the

[1] See the "cookie" entry in the Jargon file (`http://catb.org/jargon/html/C/cookie.html`) for a definition of *cookie*, and the "magic cookie" entry in the Jargon file (`http://catb.org/jargon/html/M/magic-cookie.html`) for a nice example. See also the entry for "Cookie" in the [Glossary], page 429.

actual value. You may then print an error message, or reissue the request for the actual value type, as appropriate. This behavior is summarized in Table 16.1.

		Type of Actual Value:			
		String	**Number**	**Array**	**Undefined**
	String	String	String	false	false
	Number	Number if can be converted, else false	Number	false	false
Type Requested:	**Array**	false	false	Array	false
	Scalar	Scalar	Scalar	false	false
	Undefined	String	Number	Array	Undefined
	Value Cookie	false	false	false	false

Table 16.1: Value Types Returned

16.4.4 Constructor Functions and Convenience Macros

The API provides a number of *constructor* functions for creating string and numeric values, as well as a number of convenience macros. This subsection presents them all as function prototypes, in the way that extension code would use them.

`static inline awk_value_t *`
`make_const_string(const char *string, size_t length, awk_value_t *result)`

This function creates a string value in the `awk_value_t` variable pointed to by `result`. It expects `string` to be a C string constant (or other string data), and automatically creates a *copy* of the data for storage in `result`. It returns `result`.

`static inline awk_value_t *`
`make_malloced_string(const char *string, size_t length, awk_value_t *result)`

This function creates a string value in the `awk_value_t` variable pointed to by `result`. It expects `string` to be a '`char *`' value pointing to data previously obtained from `malloc()`. The idea here is that the data is passed directly to `gawk`, which assumes responsibility for it. It returns `result`.

`static inline awk_value_t *`
`make_null_string(awk_value_t *result)`

This specialized function creates a null string (the "undefined" value) in the `awk_value_t` variable pointed to by `result`. It returns `result`.

`static inline awk_value_t *`
`make_number(double num, awk_value_t *result)`

This function simply creates a numeric value in the `awk_value_t` variable pointed to by `result`.

Two convenience macros may be used for allocating storage from `malloc()` and `realloc()`. If the allocation fails, they cause `gawk` to exit with a fatal error message. They should be used as if they were procedure calls that do not return a value.

`#define emalloc(pointer, type, size, message) ...`

The arguments to this macro are as follows:

`pointer` The pointer variable to point at the allocated storage.

`type` The type of the pointer variable, used to create a cast for the call to `malloc()`.

`size` The total number of bytes to be allocated.

`message` A message to be prefixed to the fatal error message. Typically this is the name of the function using the macro.

For example, you might allocate a string value like so:

```
awk_value_t result;
char *message;
const char greet[] = "Don’t Panic!";

emalloc(message, char *, sizeof(greet), "myfunc");
strcpy(message, greet);
make_malloced_string(message, strlen(message), & result);
```

`#define erealloc(pointer, type, size, message) ...`

This is like `emalloc()`, but it calls `realloc()`, instead of `malloc()`. The arguments are the same as for the `emalloc()` macro.

16.4.5 Registration Functions

This section describes the API functions for registering parts of your extension with `gawk`.

16.4.5.1 Registering An Extension Function

Extension functions are described by the following record:

```
typedef struct awk_ext_func {
    const char *name;
    awk_value_t *(*function)(int num_actual_args, awk_value_t *result);
    size_t num_expected_args;
} awk_ext_func_t;
```

The fields are:

`const char *name;`

The name of the new function. `awk` level code calls the function by this name. This is a regular C string.

Function names must obey the rules for `awk` identifiers. That is, they must begin with either a letter or an underscore, which may be followed by any number of letters, digits, and underscores. Letter case in function names is significant.

`awk_value_t *(*function)(int num_actual_args, awk_value_t *result);`

This is a pointer to the C function that provides the desired functionality. The function must fill in the result with either a number or a string. `awk` takes ownership of any string memory. As mentioned earlier, string memory **must** come from `malloc()`.

The `num_actual_args` argument tells the C function how many actual parameters were passed from the calling `awk` code.

The function must return the value of `result`. This is for the convenience of the calling code inside `gawk`.

`size_t num_expected_args;`
: This is the number of arguments the function expects to receive. Each extension function may decide what to do if the number of arguments isn't what it expected. Following `awk` functions, it is likely OK to ignore extra arguments.

Once you have a record representing your extension function, you register it with `gawk` using this API function:

`awk_bool_t add_ext_func(const char *namespace, const awk_ext_func_t *func);`
: This function returns true upon success, false otherwise. The `namespace` parameter is currently not used; you should pass in an empty string (`""`). The `func` pointer is the address of a `struct` representing your function, as just described.

16.4.5.2 Registering An Exit Callback Function

An *exit callback* function is a function that `gawk` calls before it exits. Such functions are useful if you have general "clean up" tasks that should be performed in your extension (such as closing data base connections or other resource deallocations). You can register such a function with `gawk` using the following function.

```
void awk_atexit(void (*funcp)(void *data, int exit_status),
                void *arg0);
```
The parameters are:

`funcp` A pointer to the function to be called before `gawk` exits. The `data` parameter will be the original value of `arg0`. The `exit_status` parameter is the exit status value that `gawk` intends to pass to the `exit()` system call.

`arg0` A pointer to private data which `gawk` saves in order to pass to the function pointed to by `funcp`.

Exit callback functions are called in Last-In-First-Out (LIFO) order—that is, in the reverse order in which they are registered with `gawk`.

16.4.5.3 Registering An Extension Version String

You can register a version string which indicates the name and version of your extension, with `gawk`, as follows:

`void register_ext_version(const char *version);`
: Register the string pointed to by `version` with `gawk`. `gawk` does *not* copy the `version` string, so it should not be changed.

`gawk` prints all registered extension version strings when it is invoked with the `--version` option.

16.4.5.4 Customized Input Parsers

By default, gawk reads text files as its input. It uses the value of RS to find the end of the record, and then uses FS (or FIELDWIDTHS or FPAT) to split it into fields (see Chapter 4 [Reading Input Files], page 55). Additionally, it sets the value of RT (see Section 7.5 [Built-in Variables], page 134).

If you want, you can provide your own custom input parser. An input parser's job is to return a record to the gawk record processing code, along with indicators for the value and length of the data to be used for RT, if any.

To provide an input parser, you must first provide two functions (where *XXX* is a prefix name for your extension):

awk_bool_t *XXX*_can_take_file(const awk_input_buf_t *iobuf)
: This function examines the information available in iobuf (which we discuss shortly). Based on the information there, it decides if the input parser should be used for this file. If so, it should return true. Otherwise, it should return false. It should not change any state (variable values, etc.) within gawk.

awk_bool_t *XXX*_take_control_of(awk_input_buf_t *iobuf)
: When gawk decides to hand control of the file over to the input parser, it calls this function. This function in turn must fill in certain fields in the awk_input_buf_t structure, and ensure that certain conditions are true. It should then return true. If an error of some kind occurs, it should not fill in any fields, and should return false; then gawk will not use the input parser. The details are presented shortly.

Your extension should package these functions inside an awk_input_parser_t, which looks like this:

```
typedef struct awk_input_parser {
    const char *name;   /* name of parser */
    awk_bool_t (*can_take_file)(const awk_input_buf_t *iobuf);
    awk_bool_t (*take_control_of)(awk_input_buf_t *iobuf);
    awk_const struct awk_input_parser *awk_const next;   /* for gawk */
} awk_input_parser_t;
```

The fields are:

const char *name;
: The name of the input parser. This is a regular C string.

awk_bool_t (*can_take_file)(const awk_input_buf_t *iobuf);
: A pointer to your *XXX*_can_take_file() function.

awk_bool_t (*take_control_of)(awk_input_buf_t *iobuf);
: A pointer to your *XXX*_take_control_of() function.

awk_const struct input_parser *awk_const next;
: This pointer is used by gawk. The extension cannot modify it.

The steps are as follows:

1. Create a static awk_input_parser_t variable and initialize it appropriately.

2. When your extension is loaded, register your input parser with `gawk` using the `register_input_parser()` API function (described below).

An `awk_input_buf_t` looks like this:

```
typedef struct awk_input {
    const char *name;       /* filename */
    int fd;                 /* file descriptor */
#define INVALID_HANDLE (-1)
    void *opaque;           /* private data for input parsers */
    int (*get_record)(char **out, struct awk_input *iobuf,
                      int *errcode, char **rt_start, size_t *rt_len);
    ssize_t (*read_func)();
    void (*close_func)(struct awk_input *iobuf);
    struct stat sbuf;       /* stat buf */
} awk_input_buf_t;
```

The fields can be divided into two categories: those for use (initially, at least) by `XXX_can_take_file()`, and those for use by `XXX_take_control_of()`. The first group of fields and their uses are as follows:

`const char *name;`
: The name of the file.

`int fd;`
: A file descriptor for the file. If `gawk` was able to open the file, then `fd` will *not* be equal to `INVALID_HANDLE`. Otherwise, it will.

`struct stat sbuf;`
: If file descriptor is valid, then `gawk` will have filled in this structure via a call to the `fstat()` system call.

The `XXX_can_take_file()` function should examine these fields and decide if the input parser should be used for the file. The decision can be made based upon `gawk` state (the value of a variable defined previously by the extension and set by `awk` code), the name of the file, whether or not the file descriptor is valid, the information in the `struct stat`, or any combination of the above.

Once `XXX_can_take_file()` has returned true, and `gawk` has decided to use your input parser, it calls `XXX_take_control_of()`. That function then fills one of either the `get_record` field or the `read_func` field in the `awk_input_buf_t`. It must also ensure that `fd` is *not* set to `INVALID_HANDLE`. All of the fields that may be filled by `XXX_take_control_of()` are as follows:

`void *opaque;`
: This is used to hold any state information needed by the input parser for this file. It is "opaque" to `gawk`. The input parser is not required to use this pointer.

```
int (*get_record)(char **out,
                  struct awk_input *iobuf,
                  int *errcode,
                  char **rt_start,
                  size_t *rt_len);
```
: This function pointer should point to a function that creates the input records. Said function is the core of the input parser. Its behavior is described below.

`ssize_t (*read_func)();`
: This function pointer should point to function that has the same behavior as the standard POSIX `read()` system call. It is an alternative to the `get_record` pointer. Its behavior is also described below.

`void (*close_func)(struct awk_input *iobuf);`
: This function pointer should point to a function that does the “tear down.” It should release any resources allocated by *XXX*`_take_control_of()`. It may also close the file. If it does so, it should set the `fd` field to `INVALID_HANDLE`.

  If `fd` is still not `INVALID_HANDLE` after the call to this function, `gawk` calls the regular `close()` system call.

  Having a “tear down” function is optional. If your input parser does not need it, do not set this field. Then, `gawk` calls the regular `close()` system call on the file descriptor, so it should be valid.

The *XXX*`_get_record()` function does the work of creating input records. The parameters are as follows:

`char **out`
: This is a pointer to a `char *` variable which is set to point to the record. `gawk` makes its own copy of the data, so the extension must manage this storage.

`struct awk_input *iobuf`
: This is the `awk_input_buf_t` for the file. The fields should be used for reading data (`fd`) and for managing private state (`opaque`), if any.

`int *errcode`
: If an error occurs, `*errcode` should be set to an appropriate code from `<errno.h>`.

`char **rt_start`
`size_t *rt_len`
: If the concept of a “record terminator” makes sense, then `*rt_start` should be set to point to the data to be used for `RT`, and `*rt_len` should be set to the length of the data. Otherwise, `*rt_len` should be set to zero. `gawk` makes its own copy of this data, so the extension must manage the storage.

The return value is the length of the buffer pointed to by `*out`, or `EOF` if end-of-file was reached or an error occurred.

It is guaranteed that `errcode` is a valid pointer, so there is no need to test for a `NULL` value. `gawk` sets `*errcode` to zero, so there is no need to set it unless an error occurs.

If an error does occur, the function should return `EOF` and set `*errcode` to a non-zero value. In that case, if `*errcode` does not equal −1, `gawk` automatically updates the `ERRNO` variable based on the value of `*errcode`. (In general, setting ‘`*errcode = errno`’ should do the right thing.)

As an alternative to supplying a function that returns an input record, you may instead supply a function that simply reads bytes, and let `gawk` parse the data into records. If you do so, the data should be returned in the multibyte encoding of the current locale. Such a function should follow the same behavior as the `read()` system call, and you fill in the `read_func` pointer with its address in the `awk_input_buf_t` structure.

By default, gawk sets the read_func pointer to point to the read() system call. So your extension need not set this field explicitly.

> **NOTE:** You must choose one method or the other: either a function that returns a record, or one that returns raw data. In particular, if you supply a function to get a record, gawk will call it, and never call the raw read function.

gawk ships with a sample extension that reads directories, returning records for each entry in the directory (see Section 16.7.6 [Reading Directories], page 381). You may wish to use that code as a guide for writing your own input parser.

When writing an input parser, you should think about (and document) how it is expected to interact with awk code. You may want it to always be called, and take effect as appropriate (as the readdir extension does). Or you may want it to take effect based upon the value of an awk variable, as the XML extension from the gawkextlib project does (see Section 16.8 [The gawkextlib Project], page 384). In the latter case, code in a BEGINFILE section can look at FILENAME and ERRNO to decide whether or not to activate an input parser (see Section 7.1.5 [The BEGINFILE and ENDFILE Special Patterns], page 123).

You register your input parser with the following function:

void register_input_parser(awk_input_parser_t *input_parser);
: Register the input parser pointed to by input_parser with gawk.

16.4.5.5 Customized Output Wrappers

An *output wrapper* is the mirror image of an input parser. It allows an extension to take over the output to a file opened with the '>' or '>>' I/O redirection operators (see Section 5.6 [Redirecting Output of print and printf], page 89).

The output wrapper is very similar to the input parser structure:

```
typedef struct awk_output_wrapper {
    const char *name;   /* name of the wrapper */
    awk_bool_t (*can_take_file)(const awk_output_buf_t *outbuf);
    awk_bool_t (*take_control_of)(awk_output_buf_t *outbuf);
    awk_const struct awk_output_wrapper *awk_const next;  /* for gawk */
} awk_output_wrapper_t;
```

The members are as follows:

const char *name;
: This is the name of the output wrapper.

awk_bool_t (*can_take_file)(const awk_output_buf_t *outbuf);
: This points to a function that examines the information in the awk_output_buf_t structure pointed to by outbuf. It should return true if the output wrapper wants to take over the file, and false otherwise. It should not change any state (variable values, etc.) within gawk.

awk_bool_t (*take_control_of)(awk_output_buf_t *outbuf);
: The function pointed to by this field is called when gawk decides to let the output wrapper take control of the file. It should fill in appropriate members of the awk_output_buf_t structure, as described below, and return true if successful, false otherwise.

`awk_const struct output_wrapper *awk_const next;`
: This is for use by gawk; therefore they are marked awk_const so that the extension cannot modify them.

The awk_output_buf_t structure looks like this:

```
typedef struct awk_output_buf {
    const char *name;   /* name of output file */
    const char *mode;   /* mode argument to fopen */
    FILE *fp;           /* stdio file pointer */
    awk_bool_t redirected;  /* true if a wrapper is active */
    void *opaque;       /* for use by output wrapper */
    size_t (*gawk_fwrite)(const void *buf, size_t size, size_t count,
                FILE *fp, void *opaque);
    int (*gawk_fflush)(FILE *fp, void *opaque);
    int (*gawk_ferror)(FILE *fp, void *opaque);
    int (*gawk_fclose)(FILE *fp, void *opaque);
} awk_output_buf_t;
```

Here too, your extension will define *XXX*_can_take_file() and *XXX*_take_control_of() functions that examine and update data members in the awk_output_buf_t. The data members are as follows:

`const char *name;`
: The name of the output file.

`const char *mode;`
: The mode string (as would be used in the second argument to fopen()) with which the file was opened.

`FILE *fp;`
: The FILE pointer from <stdio.h>. gawk opens the file before attempting to find an output wrapper.

`awk_bool_t redirected;`
: This field must be set to true by the *XXX*_take_control_of() function.

`void *opaque;`
: This pointer is opaque to gawk. The extension should use it to store a pointer to any private data associated with the file.

`size_t (*gawk_fwrite)(const void *buf, size_t size, size_t count,`
`                        FILE *fp, void *opaque);`
`int (*gawk_fflush)(FILE *fp, void *opaque);`
`int (*gawk_ferror)(FILE *fp, void *opaque);`
`int (*gawk_fclose)(FILE *fp, void *opaque);`
: These pointers should be set to point to functions that perform the equivalent function as the <stdio.h> functions do, if appropriate. gawk uses these function pointers for all output. gawk initializes the pointers to point to internal, "pass through" functions that just call the regular <stdio.h> functions, so an extension only needs to redefine those functions that are appropriate for what it does.

The *XXX*_can_take_file() function should make a decision based upon the name and mode fields, and any additional state (such as awk variable values) that is appropriate.

When gawk calls *XXX*_take_control_of(), it should fill in the other fields, as appropriate, except for fp, which it should just use normally.

You register your output wrapper with the following function:

void register_output_wrapper(awk_output_wrapper_t *output_wrapper);
: Register the output wrapper pointed to by output_wrapper with gawk.

16.4.5.6 Customized Two-way Processors

A *two-way processor* combines an input parser and an output wrapper for two-way I/O with the '|&' operator (see Section 5.6 [Redirecting Output of print and printf], page 89). It makes identical use of the awk_input_parser_t and awk_output_buf_t structures as described earlier.

A two-way processor is represented by the following structure:

```
typedef struct awk_two_way_processor {
    const char *name;   /* name of the two-way processor */
    awk_bool_t (*can_take_two_way)(const char *name);
    awk_bool_t (*take_control_of)(const char *name,
                                  awk_input_buf_t *inbuf,
                                  awk_output_buf_t *outbuf);
    awk_const struct awk_two_way_processor *awk_const next;  /* for gawk */
} awk_two_way_processor_t;
```

The fields are as follows:

const char *name;
: The name of the two-way processor.

awk_bool_t (*can_take_two_way)(const char *name);
: This function returns true if it wants to take over two-way I/O for this filename. It should not change any state (variable values, etc.) within gawk.

awk_bool_t (*take_control_of)(const char *name,
                              awk_input_buf_t *inbuf,
                              awk_output_buf_t *outbuf);
: This function should fill in the awk_input_buf_t and awk_outut_buf_t structures pointed to by inbuf and outbuf, respectively. These structures were described earlier.

awk_const struct two_way_processor *awk_const next;
: This is for use by gawk; therefore they are marked awk_const so that the extension cannot modify them.

As with the input parser and output processor, you provide "yes I can take this" and "take over for this" functions, *XXX*_can_take_two_way() and *XXX*_take_control_of().

You register your two-way processor with the following function:

void register_two_way_processor(awk_two_way_processor_t *two_way_processor);
: Register the two-way processor pointed to by two_way_processor with gawk.

16.4.6 Printing Messages

You can print different kinds of warning messages from your extension, as described below. Note that for these functions, you must pass in the extension id received from gawk when the extension was loaded.[2]

void fatal(awk_ext_id_t id, const char *format, ...);
: Print a message and then cause gawk to exit immediately.

void warning(awk_ext_id_t id, const char *format, ...);
: Print a warning message.

void lintwarn(awk_ext_id_t id, const char *format, ...);
: Print a "lint warning." Normally this is the same as printing a warning message, but if gawk was invoked with '--lint=fatal', then lint warnings become fatal error messages.

All of these functions are otherwise like the C printf() family of functions, where the format parameter is a string with literal characters and formatting codes intermixed.

16.4.7 Updating ERRNO

The following functions allow you to update the ERRNO variable:

void update_ERRNO_int(int errno_val);
: Set ERRNO to the string equivalent of the error code in errno_val. The value should be one of the defined error codes in <errno.h>, and gawk turns it into a (possibly translated) string using the C strerror() function.

void update_ERRNO_string(const char *string);
: Set ERRNO directly to the string value of ERRNO. gawk makes a copy of the value of string.

void unset_ERRNO();
: Unset ERRNO.

16.4.8 Accessing and Updating Parameters

Two functions give you access to the arguments (parameters) passed to your extension function. They are:

```
awk_bool_t get_argument(size_t count,
                        awk_valtype_t wanted,
                        awk_value_t *result);
```
: Fill in the awk_value_t structure pointed to by result with the count'th argument. Return true if the actual type matches wanted, false otherwise. In the latter case, result->val_type indicates the actual type (see Table 16.1). Counts are zero based—the first argument is numbered zero, the second one, and so on. wanted indicates the type of value expected.

awk_bool_t set_argument(size_t count, awk_array_t array);
: Convert a parameter that was undefined into an array; this provides call-by-reference for arrays. Return false if count is too big, or if the argument's type

[2] Because the API uses only ISO C 90 features, it cannot make use of the ISO C 99 variadic macro feature to hide that parameter. More's the pity.

is not undefined. See Section 16.4.10 [Array Manipulation], page 354, for more information on creating arrays.

16.4.9 Symbol Table Access

Two sets of routines provide access to global variables, and one set allows you to create and release cached values.

16.4.9.1 Variable Access and Update by Name

The following routines provide the ability to access and update global `awk`-level variables by name. In compiler terminology, identifiers of different kinds are termed *symbols*, thus the "sym" in the routines' names. The data structure which stores information about symbols is termed a *symbol table*.

```
awk_bool_t sym_lookup(const char *name,
                      awk_valtype_t wanted,
                      awk_value_t *result);
```

Fill in the `awk_value_t` structure pointed to by `result` with the value of the variable named by the string `name`, which is a regular C string. `wanted` indicates the type of value expected. Return true if the actual type matches `wanted`, false otherwise In the latter case, `result->val_type` indicates the actual type (see Table 16.1).

```
awk_bool_t sym_update(const char *name, awk_value_t *value);
```

Update the variable named by the string `name`, which is a regular C string. The variable is added to `gawk`'s symbol table if it is not there. Return true if everything worked, false otherwise.

Changing types (scalar to array or vice versa) of an existing variable is *not* allowed, nor may this routine be used to update an array. This routine cannot be used to update any of the predefined variables (such as `ARGC` or `NF`).

An extension can look up the value of `gawk`'s special variables. However, with the exception of the `PROCINFO` array, an extension cannot change any of those variables.

16.4.9.2 Variable Access and Update by Cookie

A *scalar cookie* is an opaque handle that provides access to a global variable or array. It is an optimization that avoids looking up variables in `gawk`'s symbol table every time access is needed. This was discussed earlier, in Section 16.4.2 [General Purpose Data Types], page 337.

The following functions let you work with scalar cookies.

```
awk_bool_t sym_lookup_scalar(awk_scalar_t cookie,
                             awk_valtype_t wanted,
                             awk_value_t *result);
```

Retrieve the current value of a scalar cookie. Once you have obtained a scalar_cookie using `sym_lookup()`, you can use this function to get its value more efficiently. Return false if the value cannot be retrieved.

`awk_bool_t sym_update_scalar(awk_scalar_t cookie, awk_value_t *value);`
: Update the value associated with a scalar cookie. Return false if the new value is not one of `AWK_STRING` or `AWK_NUMBER`. Here too, the built-in variables may not be updated.

It is not obvious at first glance how to work with scalar cookies or what their *raison d'être* really is. In theory, the `sym_lookup()` and `sym_update()` routines are all you really need to work with variables. For example, you might have code that looks up the value of a variable, evaluates a condition, and then possibly changes the value of the variable based on the result of that evaluation, like so:

```
/*  do_magic --- do something really great */

static awk_value_t *
do_magic(int nargs, awk_value_t *result)
{
    awk_value_t value;

    if (   sym_lookup("MAGIC_VAR", AWK_NUMBER, & value)
        && some_condition(value.num_value)) {
            value.num_value += 42;
            sym_update("MAGIC_VAR", & value);
    }

    return make_number(0.0, result);
}
```

This code looks (and is) simple and straightforward. So what's the problem?

Consider what happens if `awk`-level code associated with your extension calls the `magic()` function (implemented in C by `do_magic()`), once per record, while processing hundreds of thousands or millions of records. The `MAGIC_VAR` variable is looked up in the symbol table once or twice per function call!

The symbol table lookup is really pure overhead; it is considerably more efficient to get a cookie that represents the variable, and use that to get the variable's value and update it as needed.[3]

Thus, the way to use cookies is as follows. First, install your extension's variable in `gawk`'s symbol table using `sym_update()`, as usual. Then get a scalar cookie for the variable using `sym_lookup()`:

```
static awk_scalar_t magic_var_cookie;    /* cookie for MAGIC_VAR */

static void
my_extension_init()
{
    awk_value_t value;

    /* install initial value */
```

[3] The difference is measurable and quite real. Trust us.

```
        sym_update("MAGIC_VAR", make_number(42.0, & value));

        /* get cookie */
        sym_lookup("MAGIC_VAR", AWK_SCALAR, & value);

        /* save the cookie */
        magic_var_cookie = value.scalar_cookie;
        ...
    }
```

Next, use the routines in this section for retrieving and updating the value through the cookie. Thus, `do_magic()` now becomes something like this:

```
/*  do_magic --- do something really great */

static awk_value_t *
do_magic(int nargs, awk_value_t *result)
{
    awk_value_t value;

    if (   sym_lookup_scalar(magic_var_cookie, AWK_NUMBER, & value)
        && some_condition(value.num_value)) {
            value.num_value += 42;
            sym_update_scalar(magic_var_cookie, & value);
    }
    ...

    return make_number(0.0, result);
}
```

NOTE: The previous code omitted error checking for presentation purposes. Your extension code should be more robust and carefully check the return values from the API functions.

16.4.9.3 Creating and Using Cached Values

The routines in this section allow you to create and release cached values. As with scalar cookies, in theory, cached values are not necessary. You can create numbers and strings using the functions in Section 16.4.4 [Constructor Functions and Convenience Macros], page 340. You can then assign those values to variables using `sym_update()` or `sym_update_scalar()`, as you like.

However, you can understand the point of cached values if you remember that *every* string value's storage *must* come from `malloc()`. If you have 20 variables, all of which have the same string value, you must create 20 identical copies of the string.[4]

It is clearly more efficient, if possible, to create a value once, and then tell `gawk` to reuse the value for multiple variables. That is what the routines in this section let you do. The functions are as follows:

[4] Numeric values are clearly less problematic, requiring only a C `double` to store.

`awk_bool_t create_value(awk_value_t *value, awk_value_cookie_t *result);`
: Create a cached string or numeric value from `value` for efficient later assignment. Only `AWK_NUMBER` and `AWK_STRING` values are allowed. Any other type is rejected. While `AWK_UNDEFINED` could be allowed, doing so would result in inferior performance.

`awk_bool_t release_value(awk_value_cookie_t vc);`
: Release the memory associated with a value cookie obtained from `create_value()`.

You use value cookies in a fashion similar to the way you use scalar cookies. In the extension initialization routine, you create the value cookie:

```
static awk_value_cookie_t answer_cookie;  /* static value cookie */

static void
my_extension_init()
{
    awk_value_t value;
    char *long_string;
    size_t long_string_len;

    /* code from earlier */
    ...
    /* ... fill in long_string and long_string_len ... */
    make_malloced_string(long_string, long_string_len, & value);
    create_value(& value, & answer_cookie);    /* create cookie */
    ...
}
```

Once the value is created, you can use it as the value of any number of variables:

```
static awk_value_t *
do_magic(int nargs, awk_value_t *result)
{
    awk_value_t new_value;

    ...    /* as earlier */

    value.val_type = AWK_VALUE_COOKIE;
    value.value_cookie = answer_cookie;
    sym_update("VAR1", & value);
    sym_update("VAR2", & value);
    ...
    sym_update("VAR100", & value);
    ...
}
```

Using value cookies in this way saves considerable storage, since all of `VAR1` through `VAR100` share the same value.

You might be wondering, "Is this sharing problematic? What happens if `awk` code assigns a new value to `VAR1`, are all the others be changed too?"

That's a great question. The answer is that no, it's not a problem. Internally, `gawk` uses reference-counted strings. This means that many variables can share the same string value, and `gawk` keeps track of the usage. When a variable's value changes, `gawk` simply decrements the reference count on the old value and updates the variable to use the new value.

Finally, as part of your clean up action (see Section 16.4.5.2 [Registering An Exit Callback Function], page 342) you should release any cached values that you created, using `release_value()`.

16.4.10 Array Manipulation

The primary data structure[5] in `awk` is the associative array (see Chapter 8 [Arrays in `awk`], page 145). Extensions need to be able to manipulate `awk` arrays. The API provides a number of data structures for working with arrays, functions for working with individual elements, and functions for working with arrays as a whole. This includes the ability to "flatten" an array so that it is easy for C code to traverse every element in an array. The array data structures integrate nicely with the data structures for values to make it easy to both work with and create true arrays of arrays (see Section 16.4.2 [General Purpose Data Types], page 337).

16.4.10.1 Array Data Types

The data types associated with arrays are listed below.

`typedef void *awk_array_t;`

> If you request the value of an array variable, you get back an `awk_array_t` value. This value is opaque[6] to the extension; it uniquely identifies the array but can only be used by passing it into API functions or receiving it from API functions. This is very similar to way '`FILE *`' values are used with the `<stdio.h>` library routines.

```
typedef struct awk_element {
    /* convenience linked list pointer, not used by gawk */
    struct awk_element *next;
    enum {
        AWK_ELEMENT_DEFAULT = 0,  /* set by gawk */
        AWK_ELEMENT_DELETE = 1    /* set by extension if should be deleted */
    } flags;
    awk_value_t index;
    awk_value_t value;
} awk_element_t;
```

> The `awk_element_t` is a "flattened" array element. `awk` produces an array of these inside the `awk_flat_array_t` (see the next item). Individual elements may be marked for deletion. New elements must be added individually, one at a time, using the separate API for that purpose. The fields are as follows:

---

[5] Okay, the only data structure.

[6] It is also a "cookie," but the `gawk` developers did not wish to overuse this term.

`struct awk_element *next;`
: This pointer is for the convenience of extension writers. It allows an extension to create a linked list of new elements that can then be added to an array in a loop that traverses the list.

`enum { ... } flags;`
: A set of flag values that convey information between `gawk` and the extension. Currently there is only one: `AWK_ELEMENT_DELETE`. Setting it causes `gawk` to delete the element from the original array upon release of the flattened array.

`index`
`value`
: The index and value of the element, respectively. *All* memory pointed to by `index` and `value` belongs to `gawk`.

```
typedef struct awk_flat_array {
    awk_const void *awk_const opaque1;    /* private data for use by gawk */
    awk_const void *awk_const opaque2;    /* private data for use by gawk */
    awk_const size_t count;     /* how many elements */
    awk_element_t elements[1];  /* will be extended */
} awk_flat_array_t;
```

This is a flattened array. When an extension gets one of these from `gawk`, the `elements` array is of actual size `count`. The `opaque1` and `opaque2` pointers are for use by `gawk`; therefore they are marked `awk_const` so that the extension cannot modify them.

16.4.10.2 Array Functions

The following functions relate to individual array elements.

`awk_bool_t get_element_count(awk_array_t a_cookie, size_t *count);`
: For the array represented by `a_cookie`, return in `*count` the number of elements it contains. A subarray counts as a single element. Return false if there is an error.

```
awk_bool_t get_array_element(awk_array_t a_cookie,
                             const awk_value_t *const index,
                             awk_valtype_t wanted,
                             awk_value_t *result);
```

For the array represented by `a_cookie`, return in `*result` the value of the element whose index is `index`. `wanted` specifies the type of value you wish to retrieve. Return false if `wanted` does not match the actual type or if `index` is not in the array (see Table 16.1).

The value for `index` can be numeric, in which case `gawk` converts it to a string. Using non-integral values is possible, but requires that you understand how such values are converted to strings (see Section 6.1.4 [Conversion of Strings and Numbers], page 101); thus using integral values is safest.

As with *all* strings passed into `gawk` from an extension, the string value of `index` must come from `malloc()`, and `gawk` releases the storage.

`awk_bool_t set_array_element(awk_array_t a_cookie,`
`                              const awk_value_t *const index,`
`                              const awk_value_t *const value);`
: In the array represented by `a_cookie`, create or modify the element whose index is given by `index`. The `ARGV` and `ENVIRON` arrays may not be changed.

`awk_bool_t set_array_element_by_elem(awk_array_t a_cookie,`
`                                      awk_element_t element);`
: Like `set_array_element()`, but take the `index` and `value` from `element`. This is a convenience macro.

`awk_bool_t del_array_element(awk_array_t a_cookie,`
`                              const awk_value_t* const index);`
: Remove the element with the given index from the array represented by `a_cookie`. Return true if the element was removed, or false if the element did not exist in the array.

The following functions relate to arrays as a whole:

`awk_array_t create_array();`
: Create a new array to which elements may be added. See Section 16.4.10.4 [How To Create and Populate Arrays], page 359, for a discussion of how to create a new array and add elements to it.

`awk_bool_t clear_array(awk_array_t a_cookie);`
: Clear the array represented by `a_cookie`. Return false if there was some kind of problem, true otherwise. The array remains an array, but after calling this function, it has no elements. This is equivalent to using the `delete` statement (see Section 8.2 [The `delete` Statement], page 151).

`awk_bool_t flatten_array(awk_array_t a_cookie, awk_flat_array_t **data);`
: For the array represented by `a_cookie`, create an `awk_flat_array_t` structure and fill it in. Set the pointer whose address is passed as `data` to point to this structure. Return true upon success, or false otherwise. See Section 16.4.10.3 [Working With All The Elements of an Array], page 356, for a discussion of how to flatten an array and work with it.

`awk_bool_t release_flattened_array(awk_array_t a_cookie,`
`                                    awk_flat_array_t *data);`
: When done with a flattened array, release the storage using this function. You must pass in both the original array cookie, and the address of the created `awk_flat_array_t` structure. The function returns true upon success, false otherwise.

16.4.10.3 Working With All The Elements of an Array

To *flatten* an array is create a structure that represents the full array in a fashion that makes it easy for C code to traverse the entire array. Test code in `extension/testext.c` does this, and also serves as a nice example showing how to use the APIs.

First, the `gawk` script that drives the test extension:

```
@load "testext"
```

```
BEGIN {
    n = split("blacky rusty sophie raincloud lucky", pets)
    printf("pets has %d elements\n", length(pets))
    ret = dump_array_and_delete("pets", "3")
    printf("dump_array_and_delete(pets) returned %d\n", ret)
    if ("3" in pets)
        printf("dump_array_and_delete() did NOT remove index \"3\"!\n")
    else
        printf("dump_array_and_delete() did remove index \"3\"!\n")
    print ""
}
```

This code creates an array with `split()` (see Section 9.1.3 [String-Manipulation Functions], page 161) and then calls `dump_array_and_delete()`. That function looks up the array whose name is passed as the first argument, and deletes the element at the index passed in the second argument. The `awk` code then prints the return value and checks if the element was indeed deleted. Here is the C code that implements `dump_array_and_delete()`. It has been edited slightly for presentation.

The first part declares variables, sets up the default return value in `result`, and checks that the function was called with the correct number of arguments:

```
static awk_value_t *
dump_array_and_delete(int nargs, awk_value_t *result)
{
    awk_value_t value, value2, value3;
    awk_flat_array_t *flat_array;
    size_t count;
    char *name;
    int i;

    assert(result != NULL);
    make_number(0.0, result);

    if (nargs != 2) {
        printf("dump_array_and_delete: nargs not right "
               "(%d should be 2)\n", nargs);
        goto out;
    }
```

The function then proceeds in steps, as follows. First, retrieve the name of the array, passed as the first argument. Then retrieve the array itself. If either operation fails, print error messages and return:

```
    /* get argument named array as flat array and print it */
    if (get_argument(0, AWK_STRING, & value)) {
        name = value.str_value.str;
        if (sym_lookup(name, AWK_ARRAY, & value2))
            printf("dump_array_and_delete: sym_lookup of %s passed\n",
                   name);
        else {
```

```
            printf("dump_array_and_delete: sym_lookup of %s failed\n",
                   name);
            goto out;
        }
    } else {
        printf("dump_array_and_delete: get_argument(0) failed\n");
        goto out;
    }
```

For testing purposes and to make sure that the C code sees the same number of elements as the awk code, the second step is to get the count of elements in the array and print it:

```
    if (! get_element_count(value2.array_cookie, & count)) {
        printf("dump_array_and_delete: get_element_count failed\n");
        goto out;
    }

    printf("dump_array_and_delete: incoming size is %lu\n",
           (unsigned long) count);
```

The third step is to actually flatten the array, and then to double check that the count in the awk_flat_array_t is the same as the count just retrieved:

```
    if (! flatten_array(value2.array_cookie, & flat_array)) {
        printf("dump_array_and_delete: could not flatten array\n");
        goto out;
    }

    if (flat_array->count != count) {
        printf("dump_array_and_delete: flat_array->count (%lu)"
                " != count (%lu)\n",
                (unsigned long) flat_array->count,
                (unsigned long) count);
        goto out;
    }
```

The fourth step is to retrieve the index of the element to be deleted, which was passed as the second argument. Remember that argument counts passed to get_argument() are zero-based, thus the second argument is numbered one:

```
    if (! get_argument(1, AWK_STRING, & value3)) {
        printf("dump_array_and_delete: get_argument(1) failed\n");
        goto out;
    }
```

The fifth step is where the "real work" is done. The function loops over every element in the array, printing the index and element values. In addition, upon finding the element with the index that is supposed to be deleted, the function sets the AWK_ELEMENT_DELETE bit in the flags field of the element. When the array is released, gawk traverses the flattened array, and deletes any elements which have this flag bit set:

```
    for (i = 0; i < flat_array->count; i++) {
        printf("\t%s[\"%.*s\"] = %s\n",
```

```
                name,
                (int) flat_array->elements[i].index.str_value.len,
                flat_array->elements[i].index.str_value.str,
                valrep2str(& flat_array->elements[i].value));

            if (strcmp(value3.str_value.str,
                       flat_array->elements[i].index.str_value.str)
                       == 0) {
                flat_array->elements[i].flags |= AWK_ELEMENT_DELETE;
                printf("dump_array_and_delete: marking element \"%s\" "
                       "for deletion\n",
                    flat_array->elements[i].index.str_value.str);
            }
        }
```

The sixth step is to release the flattened array. This tells gawk that the extension is no longer using the array, and that it should delete any elements marked for deletion. gawk also frees any storage that was allocated, so you should not use the pointer (flat_array in this code) once you have called release_flattened_array():

```
        if (! release_flattened_array(value2.array_cookie, flat_array)) {
            printf("dump_array_and_delete: could not release flattened array\n");
            goto out;
        }
```

Finally, since everything was successful, the function sets the return value to success, and returns:

```
        make_number(1.0, result);
    out:
        return result;
    }
```

Here is the output from running this part of the test:

```
    pets has 5 elements
    dump_array_and_delete: sym_lookup of pets passed
    dump_array_and_delete: incoming size is 5
            pets["1"] = "blacky"
            pets["2"] = "rusty"
            pets["3"] = "sophie"
    dump_array_and_delete: marking element "3" for deletion
            pets["4"] = "raincloud"
            pets["5"] = "lucky"
    dump_array_and_delete(pets) returned 1
    dump_array_and_delete() did remove index "3"!
```

16.4.10.4 How To Create and Populate Arrays

Besides working with arrays created by awk code, you can create arrays and populate them as you see fit, and then awk code can access them and manipulate them.

There are two important points about creating arrays from extension code:

1. You must install a new array into gawk's symbol table immediately upon creating it. Once you have done so, you can then populate the array.

   Similarly, if installing a new array as a subarray of an existing array, you must add the new array to its parent before adding any elements to it.

   Thus, the correct way to build an array is to work "top down." Create the array, and immediately install it in gawk's symbol table using sym_update(), or install it as an element in a previously existing array using set_element(). We show example code shortly.
2. Due to gawk internals, after using sym_update() to install an array into gawk, you have to retrieve the array cookie from the value passed in to sym_update() before doing anything else with it, like so:

   ```
   awk_value_t value;
   awk_array_t new_array;

   new_array = create_array();
   val.val_type = AWK_ARRAY;
   val.array_cookie = new_array;

   /* install array in the symbol table */
   sym_update("array", & val);

   new_array = val.array_cookie;    /* YOU MUST DO THIS */
   ```

   If installing an array as a subarray, you must also retrieve the value of the array cookie after the call to set_element().

The following C code is a simple test extension to create an array with two regular elements and with a subarray. The leading '#include' directives and boilerplate variable declarations are omitted for brevity. The first step is to create a new array and then install it in the symbol table:

```
/* create_new_array --- create a named array */

static void
create_new_array()
{
    awk_array_t a_cookie;
    awk_array_t subarray;
    awk_value_t index, value;

    a_cookie = create_array();
    value.val_type = AWK_ARRAY;
    value.array_cookie = a_cookie;

    if (! sym_update("new_array", & value))
        printf("create_new_array: sym_update(\"new_array\") failed!\n");
    a_cookie = value.array_cookie;
```

Note how a_cookie is reset from the array_cookie field in the value structure.

The second step is to install two regular values into `new_array`:

```
    (void) make_const_string("hello", 5, & index);
    (void) make_const_string("world", 5, & value);
    if (! set_array_element(a_cookie, & index, & value)) {
        printf("fill_in_array: set_array_element failed\n");
        return;
    }

    (void) make_const_string("answer", 6, & index);
    (void) make_number(42.0, & value);
    if (! set_array_element(a_cookie, & index, & value)) {
        printf("fill_in_array: set_array_element failed\n");
        return;
    }
```

The third step is to create the subarray and install it:

```
    (void) make_const_string("subarray", 8, & index);
    subarray = create_array();
    value.val_type = AWK_ARRAY;
    value.array_cookie = subarray;
    if (! set_array_element(a_cookie, & index, & value)) {
        printf("fill_in_array: set_array_element failed\n");
        return;
    }
    subarray = value.array_cookie;
```

The final step is to populate the subarray with its own element:

```
    (void) make_const_string("foo", 3, & index);
    (void) make_const_string("bar", 3, & value);
    if (! set_array_element(subarray, & index, & value)) {
        printf("fill_in_array: set_array_element failed\n");
        return;
    }
}
```

Here is sample script that loads the extension and then dumps the array:

```
@load "subarray"

function dumparray(name, array,     i)
{
    for (i in array)
        if (isarray(array[i]))
            dumparray(name "[\"" i "\"]", array[i])
        else
            printf("%s[\"%s\"] = %s\n", name, i, array[i])
}

BEGIN {
```

```
        dumparray("new_array", new_array);
    }
```

Here is the result of running the script:

```
$ AWKLIBPATH=$PWD ./gawk -f subarray.awk
-| new_array["subarray"]["foo"] = bar
-| new_array["hello"] = world
-| new_array["answer"] = 42
```

(See Section 16.5 [How gawk Finds Extensions], page 365, for more information on the AWKLIBPATH environment variable.)

16.4.11 API Variables

The API provides two sets of variables. The first provides information about the version of the API (both with which the extension was compiled, and with which gawk was compiled). The second provides information about how gawk was invoked.

16.4.11.1 API Version Constants and Variables

The API provides both a "major" and a "minor" version number. The API versions are available at compile time as constants:

`GAWK_API_MAJOR_VERSION`
: The major version of the API.

`GAWK_API_MINOR_VERSION`
: The minor version of the API.

The minor version increases when new functions are added to the API. Such new functions are always added to the end of the API `struct`.

The major version increases (and the minor version is reset to zero) if any of the data types change size or member order, or if any of the existing functions change signature.

It could happen that an extension may be compiled against one version of the API but loaded by a version of gawk using a different version. For this reason, the major and minor API versions of the running gawk are included in the API `struct` as read-only constant integers:

`api->major_version`
: The major version of the running gawk.

`api->minor_version`
: The minor version of the running gawk.

It is up to the extension to decide if there are API incompatibilities. Typically a check like this is enough:

```
if (api->major_version != GAWK_API_MAJOR_VERSION
    || api->minor_version < GAWK_API_MINOR_VERSION) {
        fprintf(stderr, "foo_extension: version mismatch with gawk!\n");
        fprintf(stderr, "\tmy version (%d, %d), gawk version (%d, %d)\n",
                GAWK_API_MAJOR_VERSION, GAWK_API_MINOR_VERSION,
                api->major_version, api->minor_version);
        exit(1);
```

```
}
```

Such code is included in the boilerplate `dl_load_func()` macro provided in `gawkapi.h` (discussed later, in Section 16.4.12 [Boilerplate Code], page 363).

16.4.11.2 Informational Variables

The API provides access to several variables that describe whether the corresponding command-line options were enabled when `gawk` was invoked. The variables are:

`do_lint`
: This variable is true if `gawk` was invoked with `--lint` option (see Section 2.2 [Command-Line Options], page 29).

`do_traditional`
: This variable is true if `gawk` was invoked with `--traditional` option.

`do_profile`
: This variable is true if `gawk` was invoked with `--profile` option.

`do_sandbox`
: This variable is true if `gawk` was invoked with `--sandbox` option.

`do_debug`
: This variable is true if `gawk` was invoked with `--debug` option.

`do_mpfr`
: This variable is true if `gawk` was invoked with `--bignum` option.

The value of `do_lint` can change if `awk` code modifies the `LINT` built-in variable (see Section 7.5 [Built-in Variables], page 134). The others should not change during execution.

16.4.12 Boilerplate Code

As mentioned earlier (see Section 16.3 [At A High Level How It Works], page 333), the function definitions as presented are really macros. To use these macros, your extension must provide a small amount of boilerplate code (variables and functions) towards the top of your source file, using pre-defined names as described below. The boilerplate needed is also provided in comments in the `gawkapi.h` header file:

```
/* Boiler plate code: */
int plugin_is_GPL_compatible;

static gawk_api_t *const api;
static awk_ext_id_t ext_id;
static const char *ext_version = NULL; /* or ... = "some string" */

static awk_ext_func_t func_table[] = {
    { "name", do_name, 1 },
    /* ... */
};

/* EITHER: */

static awk_bool_t (*init_func)(void) = NULL;

/* OR: */
```

```
static awk_bool_t
init_my_module(void)
{
    ...
}

static awk_bool_t (*init_func)(void) = init_my_module;

dl_load_func(func_table, some_name, "name_space_in_quotes")
```

These variables and functions are as follows:

`int plugin_is_GPL_compatible;`
: This asserts that the extension is compatible with the GNU GPL (see [GNU General Public License], page 439). If your extension does not have this, `gawk` will not load it (see Section 16.2 [Extension Licensing], page 333).

`static gawk_api_t *const api;`
: This global `static` variable should be set to point to the `gawk_api_t` pointer that `gawk` passes to your `dl_load()` function. This variable is used by all of the macros.

`static awk_ext_id_t ext_id;`
: This global static variable should be set to the `awk_ext_id_t` value that `gawk` passes to your `dl_load()` function. This variable is used by all of the macros.

`static const char *ext_version = NULL; /* or ... = "some string" */`
: This global `static` variable should be set either to `NULL`, or to point to a string giving the name and version of your extension.

`static awk_ext_func_t func_table[] = { ... };`
: This is an array of one or more `awk_ext_func_t` structures as described earlier (see Section 16.4.5.1 [Registering An Extension Function], page 341). It can then be looped over for multiple calls to `add_ext_func()`.

`static awk_bool_t (*init_func)(void) = NULL;`
OR
`static awk_bool_t init_my_module(void) { ... }`
`static awk_bool_t (*init_func)(void) = init_my_module;`
: If you need to do some initialization work, you should define a function that does it (creates variables, opens files, etc.) and then define the `init_func` pointer to point to your function. The function should return `awk_false` upon failure, or `awk_true` if everything goes well.

: If you don't need to do any initialization, define the pointer and initialize it to `NULL`.

`dl_load_func(func_table, some_name, "name_space_in_quotes")`
: This macro expands to a `dl_load()` function that performs all the necessary initializations.

The point of the all the variables and arrays is to let the `dl_load()` function (from the `dl_load_func()` macro) do all the standard work. It does the following:

1. Check the API versions. If the extension major version does not match gawk's, or if the extension minor version is greater than gawk's, it prints a fatal error message and exits.
2. Load the functions defined in func_table. If any of them fails to load, it prints a warning message but continues on.
3. If the init_func pointer is not NULL, call the function it points to. If it returns awk_false, print a warning message.
4. If ext_version is not NULL, register the version string with gawk.

16.5 How gawk Finds Extensions

Compiled extensions have to be installed in a directory where gawk can find them. If gawk is configured and built in the default fashion, the directory in which to find extensions is /usr/local/lib/gawk. You can also specify a search path with a list of directories to search for compiled extensions. See Section 2.5.2 [The AWKLIBPATH Environment Variable], page 37, for more information.

16.6 Example: Some File Functions

No matter where you go, there you are.
Buckaroo Bonzai

Two useful functions that are not in awk are chdir() (so that an awk program can change its directory) and stat() (so that an awk program can gather information about a file). This section implements these functions for gawk in an extension.

16.6.1 Using chdir() and stat()

This section shows how to use the new functions at the awk level once they've been integrated into the running gawk interpreter. Using chdir() is very straightforward. It takes one argument, the new directory to change to:

```
@load "filefuncs"
...
newdir = "/home/arnold/funstuff"
ret = chdir(newdir)
if (ret < 0) {
    printf("could not change to %s: %s\n",
                   newdir, ERRNO) > "/dev/stderr"
    exit 1
}
...
```

The return value is negative if the chdir() failed, and ERRNO (see Section 7.5 [Built-in Variables], page 134) is set to a string indicating the error.

Using stat() is a bit more complicated. The C stat() function fills in a structure that has a fair amount of information. The right way to model this in awk is to fill in an associative array with the appropriate information:

```
file = "/home/arnold/.profile"
ret = stat(file, fdata)
```

```
    if (ret < 0) {
        printf("could not stat %s: %s\n",
                 file, ERRNO) > "/dev/stderr"
        exit 1
    }
    printf("size of %s is %d bytes\n", file, fdata["size"])
```

The `stat()` function always clears the data array, even if the `stat()` fails. It fills in the following elements:

`"name"` The name of the file that was `stat()`'ed.

`"dev"`
`"ino"` The file's device and inode numbers, respectively.

`"mode"` The file's mode, as a numeric value. This includes both the file's type and its permissions.

`"nlink"` The number of hard links (directory entries) the file has.

`"uid"`
`"gid"` The numeric user and group ID numbers of the file's owner.

`"size"` The size in bytes of the file.

`"blocks"` The number of disk blocks the file actually occupies. This may not be a function of the file's size if the file has holes.

`"atime"`
`"mtime"`
`"ctime"` The file's last access, modification, and inode update times, respectively. These are numeric timestamps, suitable for formatting with `strftime()` (see Section 9.1.5 [Time Functions], page 176).

`"pmode"` The file's "printable mode." This is a string representation of the file's type and permissions, such as is produced by '`ls -l`'—for example, `"drwxr-xr-x"`.

`"type"` A printable string representation of the file's type. The value is one of the following:

  `"blockdev"`
  `"chardev"`
  The file is a block or character device ("special file").

  `"directory"`
  The file is a directory.

  `"fifo"` The file is a named-pipe (also known as a FIFO).

  `"file"` The file is just a regular file.

  `"socket"` The file is an `AF_UNIX` ("Unix domain") socket in the filesystem.

  `"symlink"`
  The file is a symbolic link.

"devbsize"
: The size of a block for the element indexed by "blocks". This information is derived from either the DEV_BSIZE constant defined in <sys/param.h> on most systems, or the S_BLKSIZE constant in <sys/stat.h> on BSD systems. For some other systems, *a priori* knowledge is used to provide a value. Where no value can be determined, it defaults to 512.

Several additional elements may be present depending upon the operating system and the type of the file. You can test for them in your awk program by using the in operator (see Section 8.1.2 [Referring to an Array Element], page 146):

"blksize"
: The preferred block size for I/O to the file. This field is not present on all POSIX-like systems in the C stat structure.

"linkval"
: If the file is a symbolic link, this element is the name of the file the link points to (i.e., the value of the link).

"rdev"
"major"
"minor"
: If the file is a block or character device file, then these values represent the numeric device number and the major and minor components of that number, respectively.

16.6.2 C Code for chdir() and stat()

Here is the C code for these extensions.[7]

The file includes a number of standard header files, and then includes the gawkapi.h header file which provides the API definitions. Those are followed by the necessary variable declarations to make use of the API macros and boilerplate code (see Section 16.4.12 [Boilerplate Code], page 363).

```
#ifdef HAVE_CONFIG_H
#include <config.h>
#endif

#include <stdio.h>
#include <assert.h>
#include <errno.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>

#include <sys/types.h>
#include <sys/stat.h>

#include "gawkapi.h"
```

[7] This version is edited slightly for presentation. See extension/filefuncs.c in the gawk distribution for the complete version.

```
#include "gettext.h"
#define _(msgid)  gettext(msgid)
#define N_(msgid) msgid

#include "gawkfts.h"
#include "stack.h"

static const gawk_api_t *api;    /* for convenience macros to work */
static awk_ext_id_t *ext_id;
static awk_bool_t init_filefuncs(void);
static awk_bool_t (*init_func)(void) = init_filefuncs;
static const char *ext_version = "filefuncs extension: version 1.0";

int plugin_is_GPL_compatible;
```

By convention, for an awk function foo(), the C function that implements it is called do_foo(). The function should have two arguments: the first is an int usually called nargs, that represents the number of actual arguments for the function. The second is a pointer to an awk_value_t, usually named result.

```
/*  do_chdir --- provide dynamically loaded chdir() builtin for gawk */

static awk_value_t *
do_chdir(int nargs, awk_value_t *result)
{
    awk_value_t newdir;
    int ret = -1;

    assert(result != NULL);

    if (do_lint && nargs != 1)
        lintwarn(ext_id,
                 _("chdir: called with incorrect number of arguments, "
                   "expecting 1"));
```

The newdir variable represents the new directory to change to, retrieved with get_argument(). Note that the first argument is numbered zero.

If the argument is retrieved successfully, the function calls the chdir() system call. If the chdir() fails, ERRNO is updated.

```
    if (get_argument(0, AWK_STRING, & newdir)) {
        ret = chdir(newdir.str_value.str);
        if (ret < 0)
            update_ERRNO_int(errno);
    }
```

Finally, the function returns the return value to the awk level:

```
    return make_number(ret, result);
}
```

The `stat()` extension is more involved. First comes a function that turns a numeric mode into a printable representation (e.g., 644 becomes '-rw-r--r--'). This is omitted here for brevity:

```
/* format_mode --- turn a stat mode field into something readable */

static char *
format_mode(unsigned long fmode)
{
    ...
}
```

Next comes a function for reading symbolic links, which is also omitted here for brevity:

```
/* read_symlink --- read a symbolic link into an allocated buffer.
   ... */

static char *
read_symlink(const char *fname, size_t bufsize, ssize_t *linksize)
{
    ...
}
```

Two helper functions simplify entering values in the array that will contain the result of the `stat()`:

```
/* array_set --- set an array element */

static void
array_set(awk_array_t array, const char *sub, awk_value_t *value)
{
    awk_value_t index;

    set_array_element(array,
                      make_const_string(sub, strlen(sub), & index),
                      value);

}

/* array_set_numeric --- set an array element with a number */

static void
array_set_numeric(awk_array_t array, const char *sub, double num)
{
    awk_value_t tmp;

    array_set(array, sub, make_number(num, & tmp));
}
```

The following function does most of the work to fill in the `awk_array_t` result array with values obtained from a valid `struct stat`. It is done in a separate function to support the stat() function for gawk and also to support the fts() extension which is included in the same file but whose code is not shown here (see Section 16.7.1 [File Related Functions], page 375).

The first part of the function is variable declarations, including a table to map file types to strings:

```
/* fill_stat_array --- do the work to fill an array with stat info */

static int
fill_stat_array(const char *name, awk_array_t array, struct stat *sbuf)
{
    char *pmode;    /* printable mode */
    const char *type = "unknown";
    awk_value_t tmp;
    static struct ftype_map {
        unsigned int mask;
        const char *type;
    } ftype_map[] = {
        { S_IFREG, "file" },
        { S_IFBLK, "blockdev" },
        { S_IFCHR, "chardev" },
        { S_IFDIR, "directory" },
#ifdef S_IFSOCK
        { S_IFSOCK, "socket" },
#endif
#ifdef S_IFIFO
        { S_IFIFO, "fifo" },
#endif
#ifdef S_IFLNK
        { S_IFLNK, "symlink" },
#endif
#ifdef S_IFDOOR /* Solaris weirdness */
        { S_IFDOOR, "door" },
#endif /* S_IFDOOR */
    };
    int j, k;
```

The destination array is cleared, and then code fills in various elements based on values in the struct stat:

```
    /* empty out the array */
    clear_array(array);

    /* fill in the array */
    array_set(array, "name", make_const_string(name, strlen(name),
                                               & tmp));
    array_set_numeric(array, "dev", sbuf->st_dev);
    array_set_numeric(array, "ino", sbuf->st_ino);
    array_set_numeric(array, "mode", sbuf->st_mode);
```

```
    array_set_numeric(array, "nlink", sbuf->st_nlink);
    array_set_numeric(array, "uid", sbuf->st_uid);
    array_set_numeric(array, "gid", sbuf->st_gid);
    array_set_numeric(array, "size", sbuf->st_size);
    array_set_numeric(array, "blocks", sbuf->st_blocks);
    array_set_numeric(array, "atime", sbuf->st_atime);
    array_set_numeric(array, "mtime", sbuf->st_mtime);
    array_set_numeric(array, "ctime", sbuf->st_ctime);

    /* for block and character devices, add rdev,
       major and minor numbers */
    if (S_ISBLK(sbuf->st_mode) || S_ISCHR(sbuf->st_mode)) {
        array_set_numeric(array, "rdev", sbuf->st_rdev);
        array_set_numeric(array, "major", major(sbuf->st_rdev));
        array_set_numeric(array, "minor", minor(sbuf->st_rdev));
    }
```

The latter part of the function makes selective additions to the destination array, depending upon the availability of certain members and/or the type of the file. It then returns zero, for success:

```
#ifdef HAVE_STRUCT_STAT_ST_BLKSIZE
    array_set_numeric(array, "blksize", sbuf->st_blksize);
#endif /* HAVE_STRUCT_STAT_ST_BLKSIZE */

    pmode = format_mode(sbuf->st_mode);
    array_set(array, "pmode", make_const_string(pmode, strlen(pmode),
                                                & tmp));

    /* for symbolic links, add a linkval field */
    if (S_ISLNK(sbuf->st_mode)) {
        char *buf;
        ssize_t linksize;

        if ((buf = read_symlink(name, sbuf->st_size,
                    & linksize)) != NULL)
            array_set(array, "linkval",
                      make_malloced_string(buf, linksize, & tmp));
        else
            warning(ext_id, _("stat: unable to read symbolic link ‘%s’"),
                    name);
    }

    /* add a type field */
    type = "unknown";   /* shouldn’t happen */
    for (j = 0, k = sizeof(ftype_map)/sizeof(ftype_map[0]); j < k; j++) {
        if ((sbuf->st_mode & S_IFMT) == ftype_map[j].mask) {
            type = ftype_map[j].type;
```

```
                break;
            }
        }

        array_set(array, "type", make_const_string(type, strlen(type), &tmp));

        return 0;
    }
```

Finally, here is the `do_stat()` function. It starts with variable declarations and argument checking:

```
    /* do_stat --- provide a stat() function for gawk */

    static awk_value_t *
    do_stat(int nargs, awk_value_t *result)
    {
        awk_value_t file_param, array_param;
        char *name;
        awk_array_t array;
        int ret;
        struct stat sbuf;
        /* default is stat() */
        int (*statfunc)(const char *path, struct stat *sbuf) = lstat;

        assert(result != NULL);

        if (nargs != 2 && nargs != 3) {
            if (do_lint)
                lintwarn(ext_id,
                   _("stat: called with wrong number of arguments"));
            return make_number(-1, result);
        }
```

The third argument to `stat()` was not discussed previously. This argument is optional. If present, it causes `stat()` to use the `stat()` system call instead of the `lstat()` system call.

Then comes the actual work. First, the function gets the arguments. Next, it gets the information for the file. The code use `lstat()` (instead of `stat()`) to get the file information, in case the file is a symbolic link. If there's an error, it sets `ERRNO` and returns:

```
        /* file is first arg, array to hold results is second */
        if (    ! get_argument(0, AWK_STRING, & file_param)
            || ! get_argument(1, AWK_ARRAY, & array_param)) {
            warning(ext_id, _("stat: bad parameters"));
            return make_number(-1, result);
        }

        if (nargs == 3) {
            statfunc = stat;
```

```
    }

    name = file_param.str_value.str;
    array = array_param.array_cookie;

    /* always empty out the array */
    clear_array(array);

    /* stat the file, if error, set ERRNO and return */
    ret = statfunc(name, & sbuf);
    if (ret < 0) {
        update_ERRNO_int(errno);
        return make_number(ret, result);
    }
```

The tedious work is done by `fill_stat_array()`, shown earlier. When done, return the result from `fill_stat_array()`:

```
    ret = fill_stat_array(name, array, & sbuf);

    return make_number(ret, result);
}
```

Finally, it's necessary to provide the "glue" that loads the new function(s) into `gawk`.

The `filefuncs` extension also provides an `fts()` function, which we omit here. For its sake there is an initialization function:

```
/* init_filefuncs --- initialization routine */

static awk_bool_t
init_filefuncs(void)
{
    ...
}
```

We are almost done. We need an array of `awk_ext_func_t` structures for loading each function into `gawk`:

```
static awk_ext_func_t func_table[] = {
    { "chdir", do_chdir, 1 },
    { "stat",  do_stat, 2 },
    { "fts",   do_fts, 3 },
};
```

Each extension must have a routine named `dl_load()` to load everything that needs to be loaded. It is simplest to use the `dl_load_func()` macro in `gawkapi.h`:

```
/* define the dl_load() function using the boilerplate macro */

dl_load_func(func_table, filefuncs, "")
```

And that's it! As an exercise, consider adding functions to implement system calls such as `chown()`, `chmod()`, and `umask()`.

16.6.3 Integrating The Extensions

Now that the code is written, it must be possible to add it at runtime to the running `gawk` interpreter. First, the code must be compiled. Assuming that the functions are in a file named `filefuncs.c`, and *idir* is the location of the `gawkapi.h` header file, the following steps[8] create a GNU/Linux shared library:

```
$ gcc -fPIC -shared -DHAVE_CONFIG_H -c -O -g -Iidir filefuncs.c
$ gcc -o filefuncs.so -shared filefuncs.o
```

Once the library exists, it is loaded by using the `@load` keyword.

```
# file testff.awk
@load "filefuncs"

BEGIN {
    "pwd" | getline curdir  # save current directory
    close("pwd")

    chdir("/tmp")
    system("pwd")   # test it
    chdir(curdir)   # go back

    print "Info for testff.awk"
    ret = stat("testff.awk", data)
    print "ret =", ret
    for (i in data)
        printf "data[\"%s\"] = %s\n", i, data[i]
    print "testff.awk modified:",
        strftime("%m %d %y %H:%M:%S", data["mtime"])

    print "\nInfo for JUNK"
    ret = stat("JUNK", data)
    print "ret =", ret
    for (i in data)
        printf "data[\"%s\"] = %s\n", i, data[i]
    print "JUNK modified:", strftime("%m %d %y %H:%M:%S", data["mtime"])
}
```

The `AWKLIBPATH` environment variable tells `gawk` where to find shared libraries (see Section 16.5 [How gawk Finds Extensions], page 365). We set it to the current directory and run the program:

```
$ AWKLIBPATH=$PWD gawk -f testff.awk
⊣ /tmp
⊣ Info for testff.awk
⊣ ret = 0
⊣ data["blksize"] = 4096
```

[8] In practice, you would probably want to use the GNU Autotools—Automake, Autoconf, Libtool, and Gettext—to configure and build your libraries. Instructions for doing so are beyond the scope of this book. See Section 16.8 [The `gawkextlib` Project], page 384, for WWW links to the tools.

```
⊣ data["mtime"] = 1350838628
⊣ data["mode"] = 33204
⊣ data["type"] = file
⊣ data["dev"] = 2053
⊣ data["gid"] = 1000
⊣ data["ino"] = 1719496
⊣ data["ctime"] = 1350838628
⊣ data["blocks"] = 8
⊣ data["nlink"] = 1
⊣ data["name"] = testff.awk
⊣ data["atime"] = 1350838632
⊣ data["pmode"] = -rw-rw-r--
⊣ data["size"] = 662
⊣ data["uid"] = 1000
⊣ testff.awk modified: 10 21 12 18:57:08
⊣
⊣ Info for JUNK
⊣ ret = -1
⊣ JUNK modified: 01 01 70 02:00:00
```

16.7 The Sample Extensions In The gawk Distribution

This section provides brief overviews of the sample extensions that come in the `gawk` distribution. Some of them are intended for production use, such the `filefuncs`, `readdir` and `inplace` extensions. Others mainly provide example code that shows how to use the extension API.

16.7.1 File Related Functions

The `filefuncs` extension provides three different functions, as follows: The usage is:

`@load "filefuncs"`
: This is how you load the extension.

`result = chdir("/some/directory")`
: The `chdir()` function is a direct hook to the `chdir()` system call to change the current directory. It returns zero upon success or less than zero upon error. In the latter case it updates `ERRNO`.

`result = stat("/some/path", statdata [, follow])`
: The `stat()` function provides a hook into the `stat()` system call. It returns zero upon success or less than zero upon error. In the latter case it updates `ERRNO`.

  By default, it uses the `lstat()` system call. However, if passed a third argument, it uses `stat()` instead.

  In all cases, it clears the `statdata` array. When the call is successful, `stat()` fills the `statdata` array with information retrieved from the filesystem, as follows:

  `statdata["name"]` The name of the file.

statdata["dev"] Corresponds to the st_dev field in the struct stat.

statdata["ino"] Corresponds to the st_ino field in the struct stat.

statdata["mode"] Corresponds to the st_mode field in the struct stat.

statdata["nlink"] Corresponds to the st_nlink field in the struct stat.

statdata["uid"] Corresponds to the st_uid field in the struct stat.

statdata["gid"] Corresponds to the st_gid field in the struct stat.

statdata["size"] Corresponds to the st_size field in the struct stat.

statdata["atime"] Corresponds to the st_atime field in the struct stat.

statdata["mtime"] Corresponds to the st_mtime field in the struct stat.

statdata["ctime"] Corresponds to the st_ctime field in the struct stat.

statdata["rdev"] Corresponds to the st_rdev field in the struct stat. This element is only present for device files.

statdata["major"] Corresponds to the st_major field in the struct stat. This element is only present for device files.

statdata["minor"] Corresponds to the st_minor field in the struct stat. This element is only present for device files.

statdata["blksize"] Corresponds to the st_blksize field in the struct stat, if this field is present on your system. (It is present on all modern systems that we know of.)

statdata["pmode"] A human-readable version of the mode value, such as printed by ls. For example, "-rwxr-xr-x".

statdata["linkval"] If the named file is a symbolic link, this element will exist and its value is the value of the symbolic link (where the symbolic link points to).

`statdata["type"]` The type of the file as a string. One of `"file"`, `"blockdev"`, `"chardev"`, `"directory"`, `"socket"`, `"fifo"`, `"symlink"`, `"door"`, or `"unknown"`. Not all systems support all file types.

`flags = or(FTS_PHYSICAL, ...)`
`result = fts(pathlist, flags, filedata)`
Walk the file trees provided in `pathlist` and fill in the `filedata` array as described below. `flags` is the bitwise OR of several predefined constant values, also described below. Return zero if there were no errors, otherwise return −1.

The `fts()` function provides a hook to the C library `fts()` routines for traversing file hierarchies. Instead of returning data about one file at a time in a stream, it fills in a multidimensional array with data about each file and directory encountered in the requested hierarchies.

The arguments are as follows:

`pathlist` An array of filenames. The element values are used; the index values are ignored.

`flags` This should be the bitwise OR of one or more of the following predefined constant flag values. At least one of `FTS_LOGICAL` or `FTS_PHYSICAL` must be provided; otherwise `fts()` returns an error value and sets `ERRNO`. The flags are:

`FTS_LOGICAL`
Do a "logical" file traversal, where the information returned for a symbolic link refers to the linked-to file, and not to the symbolic link itself. This flag is mutually exclusive with `FTS_PHYSICAL`.

`FTS_PHYSICAL`
Do a "physical" file traversal, where the information returned for a symbolic link refers to the symbolic link itself. This flag is mutually exclusive with `FTS_LOGICAL`.

`FTS_NOCHDIR`
As a performance optimization, the C library `fts()` routines change directory as they traverse a file hierarchy. This flag disables that optimization.

`FTS_COMFOLLOW`
Immediately follow a symbolic link named in `pathlist`, whether or not `FTS_LOGICAL` is set.

`FTS_SEEDOT`
By default, the `fts()` routines do not return entries for `.` (dot) and `..` (dot-dot). This option causes entries for dot-dot to also be included. (The extension always includes an entry for dot, see below.)

`FTS_XDEV` During a traversal, do not cross onto a different mounted filesystem.

`filedata` The `filedata` array is first cleared. Then, `fts()` creates an element in `filedata` for every element in `pathlist`. The index is the name of the directory or file given in `pathlist`. The element for this index is itself an array. There are two cases.

The path is a file
In this case, the array contains two or three elements:

`"path"` The full path to this file, starting from the "root" that was given in the `pathlist` array.

`"stat"` This element is itself an array, containing the same information as provided by the `stat()` function described earlier for its `statdata` argument. The element may not be present if the `stat()` system call for the file failed.

`"error"` If some kind of error was encountered, the array will also contain an element named `"error"`, which is a string describing the error.

The path is a directory
In this case, the array contains one element for each entry in the directory. If an entry is a file, that element is as for files, just described. If the entry is a directory, that element is (recursively), an array describing the subdirectory. If `FTS_SEEDOT` was provided in the flags, then there will also be an element named `".."`. This element will be an array containing the data as provided by `stat()`.

In addition, there will be an element whose index is `"."`. This element is an array containing the same two or three elements as for a file: `"path"`, `"stat"`, and `"error"`.

The `fts()` function returns zero if there were no errors. Otherwise it returns −1.

> **NOTE:** The `fts()` extension does not exactly mimic the interface of the C library `fts()` routines, choosing instead to provide an interface that is based on associative arrays, which should be more comfortable to use from an `awk` program. This includes the lack of a comparison function, since `gawk` already provides powerful array sorting facilities. While an `fts_read()`-like interface could have been provided, this felt less natural than simply creating a multidimensional array to represent the file hierarchy and its information.

See `test/fts.awk` in the `gawk` distribution for an example.

16.7.2 Interface To `fnmatch()`

This extension provides an interface to the C library `fnmatch()` function. The usage is:

```
@load "fnmatch"

result = fnmatch(pattern, string, flags)
```

The `fnmatch` extension adds a single function named `fnmatch()`, one constant (`FNM_NOMATCH`), and an array of flag values named `FNM`.

The arguments to `fnmatch()` are:

`pattern` The filename wildcard to match.

`string` The filename string.

`flag` Either zero, or the bitwise OR of one or more of the flags in the `FNM` array.

The return value is zero on success, `FNM_NOMATCH` if the string did not match the pattern, or a different non-zero value if an error occurred.

The flags are follows:

`FNM["CASEFOLD"]` Corresponds to the `FNM_CASEFOLD` flag as defined in `fnmatch()`.

`FNM["FILE_NAME"]` Corresponds to the `FNM_FILE_NAME` flag as defined in `fnmatch()`.

`FNM["LEADING_DIR"]` Corresponds to the `FNM_LEADING_DIR` flag as defined in `fnmatch()`.

`FNM["NOESCAPE"]` Corresponds to the `FNM_NOESCAPE` flag as defined in `fnmatch()`.

`FNM["PATHNAME"]` Corresponds to the `FNM_PATHNAME` flag as defined in `fnmatch()`.

`FNM["PERIOD"]` Corresponds to the `FNM_PERIOD` flag as defined in `fnmatch()`.

Here is an example:

```
@load "fnmatch"
...
flags = or(FNM["PERIOD"], FNM["NOESCAPE"])
if (fnmatch("*.a", "foo.c", flags) == FNM_NOMATCH)
    print "no match"
```

16.7.3 Interface To fork(), wait() and waitpid()

The `fork` extension adds three functions, as follows.

`@load "fork"`
: This is how you load the extension.

`pid = fork()`
: This function creates a new process. The return value is the zero in the child and the process-id number of the child in the parent, or −1 upon error. In the latter case, `ERRNO` indicates the problem. In the child, `PROCINFO["pid"]` and `PROCINFO["ppid"]` are updated to reflect the correct values.

`ret = waitpid(pid)`
: This function takes a numeric argument, which is the process-id to wait for. The return value is that of the `waitpid()` system call.

`ret = wait()`
: This function waits for the first child to die. The return value is that of the `wait()` system call.

There is no corresponding `exec()` function.

Here is an example:

```
@load "fork"
...
if ((pid = fork()) == 0)
```

```
        print "hello from the child"
    else
        print "hello from the parent"
```

16.7.4 Enabling In-Place File Editing

The `inplace` extension emulates GNU `sed`'s `-i` option which performs "in place" editing of each input file. It uses the bundled `inplace.awk` include file to invoke the extension properly:

```
# inplace --- load and invoke the inplace extension.

@load "inplace"

# Please set INPLACE_SUFFIX to make a backup copy.  For example, you may
# want to set INPLACE_SUFFIX to .bak on the command line or in a BEGIN rule.

BEGINFILE {
    inplace_begin(FILENAME, INPLACE_SUFFIX)
}

ENDFILE {
    inplace_end(FILENAME, INPLACE_SUFFIX)
}
```

For each regular file that is processed, the extension redirects standard output to a temporary file configured to have the same owner and permissions as the original. After the file has been processed, the extension restores standard output to its original destination. If `INPLACE_SUFFIX` is not an empty string, the original file is linked to a backup filename created by appending that suffix. Finally, the temporary file is renamed to the original filename.

If any error occurs, the extension issues a fatal error to terminate processing immediately without damaging the original file.

Here are some simple examples:

```
$ gawk -i inplace '{ gsub(/foo/, "bar") }; { print }' file1 file2 file3
```

To keep a backup copy of the original files, try this:

```
$ gawk -i inplace -v INPLACE_SUFFIX=.bak '{ gsub(/foo/, "bar") }
> { print }' file1 file2 file3
```

We leave it as an exercise to write a wrapper script that presents an interface similar to '`sed -i`'.

16.7.5 Character and Numeric values: `ord()` and `chr()`

The `ordchr` extension adds two functions, named `ord()` and `chr()`, as follows.

`@load "ordchr"`
: This is how you load the extension.

`number = ord(string)`
: Return the numeric value of the first character in `string`.

`char = chr(number)`
Return a string whose first character is that represented by `number`.

These functions are inspired by the Pascal language functions of the same name. Here is an example:

```
@load "ordchr"
...
printf("The numeric value of 'A' is %d\n", ord("A"))
printf("The string value of 65 is %s\n", chr(65))
```

16.7.6 Reading Directories

The `readdir` extension adds an input parser for directories. The usage is as follows:

```
@load "readdir"
```

When this extension is in use, instead of skipping directories named on the command line (or with `getline`), they are read, with each entry returned as a record.

The record consists of three fields. The first two are the inode number and the filename, separated by a forward slash character. On systems where the directory entry contains the file type, the record has a third field (also separated by a slash) which is a single letter indicating the type of the file:

Letter	File Type
b	Block device
c	Character device
d	Directory
f	Regular file
l	Symbolic link
p	Named pipe (FIFO)
s	Socket
u	Anything else (unknown)

On systems without the file type information, the third field is always '`u`'.

> **NOTE:** On GNU/Linux systems, there are filesystems that don't support the `d_type` entry (see the *readdir*(3) manual page), and so the file type is always '`u`'. You can use the `filefuncs` extension to call `stat()` in order to get correct type information.

Here is an example:

```
@load "readdir"
...
BEGIN { FS = "/" }
{ print "file name is", $2 }
```

16.7.7 Reversing Output

The `revoutput` extension adds a simple output wrapper that reverses the characters in each output line. It's main purpose is to show how to write an output wrapper, although it may be mildly amusing for the unwary. Here is an example:

```
@load "revoutput"

BEGIN {
    REVOUT = 1
    print "hello, world" > "/dev/stdout"
}
```

The output from this program is: ‘dlrow ,olleh’.

16.7.8 Two-Way I/O Example

The revtwoway extension adds a simple two-way processor that reverses the characters in each line sent to it for reading back by the awk program. It’s main purpose is to show how to write a two-way processor, although it may also be mildly amusing. The following example shows how to use it:

```
@load "revtwoway"

BEGIN {
    cmd = "/magic/mirror"
    print "hello, world" |& cmd
    cmd |& getline result
    print result
    close(cmd)
}
```

16.7.9 Dumping and Restoring An Array

The rwarray extension adds two functions, named writea() and reada(), as follows:

ret = writea(file, array)
: This function takes a string argument, which is the name of the file to which dump the array, and the array itself as the second argument. writea() understands multidimensional arrays. It returns one on success, or zero upon failure.

ret = reada(file, array)
: reada() is the inverse of writea(); it reads the file named as its first argument, filling in the array named as the second argument. It clears the array first. Here too, the return value is one on success and zero upon failure.

The array created by reada() is identical to that written by writea() in the sense that the contents are the same. However, due to implementation issues, the array traversal order of the recreated array is likely to be different from that of the original array. As array traversal order in awk is by default undefined, this is (technically) not a problem. If you need to guarantee a particular traversal order, use the array sorting features in gawk to do so (see Section 12.2 [Controlling Array Traversal and Array Sorting], page 278).

The file contains binary data. All integral values are written in network byte order. However, double precision floating-point values are written as native binary data. Thus, arrays containing only string data can theoretically be dumped on systems with one byte order and restored on systems with a different one, but this has not been tried.

Here is an example:

```
@load "rwarray"
...
ret = writea("arraydump.bin", array)
...
ret = reada("arraydump.bin", array)
```

16.7.10 Reading An Entire File

The `readfile` extension adds a single function named `readfile()`:

`@load "readfile"`
: This is how you load the extension.

`result = readfile("/some/path")`
: The argument is the name of the file to read. The return value is a string containing the entire contents of the requested file. Upon error, the function returns the empty string and sets `ERRNO`.

Here is an example:

```
@load "readfile"
...
contents = readfile("/path/to/file");
if (contents == "" && ERRNO != "") {
    print("problem reading file", ERRNO) > "/dev/stderr"
    ...
}
```

16.7.11 API Tests

The `testext` extension exercises parts of the extension API that are not tested by the other samples. The `extension/testext.c` file contains both the C code for the extension and `awk` test code inside C comments that run the tests. The testing framework extracts the `awk` code and runs the tests. See the source file for more information.

16.7.12 Extension Time Functions

These functions can be used either by invoking `gawk` with a command-line argument of '`-l time`' or by inserting '`@load "time"`' in your script.

`@load "time"`
: This is how you load the extension.

`the_time = gettimeofday()`
: Return the time in seconds that has elapsed since 1970-01-01 UTC as a floating point value. If the time is unavailable on this platform, return −1 and set `ERRNO`. The returned time should have sub-second precision, but the actual precision may vary based on the platform. If the standard C `gettimeofday()` system call is available on this platform, then it simply returns the value. Otherwise, if on Windows, it tries to use `GetSystemTimeAsFileTime()`.

`result = sleep(`*`seconds`*`)`
: Attempt to sleep for *seconds* seconds. If *seconds* is negative, or the attempt to sleep fails, return −1 and set `ERRNO`. Otherwise, return zero after sleeping for

the indicated amount of time. Note that *seconds* may be a floating-point (non-integral) value. Implementation details: depending on platform availability, this function tries to use `nanosleep()` or `select()` to implement the delay.

16.8 The `gawkextlib` Project

The `gawkextlib` (`http://sourceforge.net/projects/gawkextlib/`) project provides a number of `gawk` extensions, including one for processing XML files. This is the evolution of the original `xgawk` (XML `gawk`) project.

As of this writing, there are four extensions:

- XML parser extension, using the Expat (`http://expat.sourceforge.net`) XML parsing library.
- PostgreSQL extension.
- GD graphics library extension.
- MPFR library extension. This provides access to a number of MPFR functions which `gawk`'s native MPFR support does not.

The `time` extension described earlier (see Section 16.7.12 [Extension Time Functions], page 383) was originally from this project but has been moved in to the main `gawk` distribution.

You can check out the code for the `gawkextlib` project using the GIT (`http://git-scm.com`) distributed source code control system. The command is as follows:

```
git clone git://git.code.sf.net/p/gawkextlib/code gawkextlib-code
```

You will need to have the Expat (`http://expat.sourceforge.net`) XML parser library installed in order to build and use the XML extension.

In addition, you must have the GNU Autotools installed (Autoconf (`http://www.gnu.org/software/autoconf`), Automake (`http://www.gnu.org/software/automake`), Libtool (`http://www.gnu.org/software/libtool`), and Gettext (`http://www.gnu.org/software/gettext`)).

The simple recipe for building and testing `gawkextlib` is as follows. First, build and install `gawk`:

```
cd .../path/to/gawk/code
./configure --prefix=/tmp/newgawk     Install in /tmp/newgawk for now
make && make check                    Build and check that all is OK
make install                          Install gawk
```

Next, build `gawkextlib` and test it:

```
cd .../path/to/gawkextlib-code
./update-autotools                    Generate configure, etc.
                                      You may have to run this command twice
./configure --with-gawk=/tmp/newgawk  Configure, point at ‘‘installed’’ gawk
make && make check                    Build and check that all is OK
make install                          Install the extensions
```

If you have installed `gawk` in the standard way, then you will likely not need the `--with-gawk` option when configuring `gawkextlib`. You may also need to use the `sudo` utility to install both `gawk` and `gawkextlib`, depending upon how your system works.

If you write an extension that you wish to share with other gawk users, please consider doing so through the gawkextlib project. See the project's web site for more information.

Part IV:
Appendices

Appendix A The Evolution of the awk Language

This book describes the GNU implementation of awk, which follows the POSIX specification. Many long-time awk users learned awk programming with the original awk implementation in Version 7 Unix. (This implementation was the basis for awk in Berkeley Unix, through 4.3-Reno. Subsequent versions of Berkeley Unix, and some systems derived from 4.4BSD-Lite, use various versions of gawk for their awk.) This chapter briefly describes the evolution of the awk language, with cross-references to other parts of the book where you can find more information.

A.1 Major Changes Between V7 and SVR3.1

The awk language evolved considerably between the release of Version 7 Unix (1978) and the new version that was first made generally available in System V Release 3.1 (1987). This section summarizes the changes, with cross-references to further details:

- The requirement for ‘;’ to separate rules on a line (see Section 1.6 [awk Statements Versus Lines], page 25).
- User-defined functions and the return statement (see Section 9.2 [User-Defined Functions], page 184).
- The delete statement (see Section 8.2 [The delete Statement], page 151).
- The do-while statement (see Section 7.4.3 [The do-while Statement], page 128).
- The built-in functions atan2(), cos(), sin(), rand(), and srand() (see Section 9.1.2 [Numeric Functions], page 159).
- The built-in functions gsub(), sub(), and match() (see Section 9.1.3 [String-Manipulation Functions], page 161).
- The built-in functions close() and system() (see Section 9.1.4 [Input/Output Functions], page 173).
- The ARGC, ARGV, FNR, RLENGTH, RSTART, and SUBSEP built-in variables (see Section 7.5 [Built-in Variables], page 134).
- Assignable $0 (see Section 4.4 [Changing the Contents of a Field], page 60).
- The conditional expression using the ternary operator ‘?:’ (see Section 6.3.4 [Conditional Expressions], page 115).
- The expression ‘*index-variable* in *array*’ outside of for statements (see Section 8.1.2 [Referring to an Array Element], page 146).
- The exponentiation operator ‘^’ (see Section 6.2.1 [Arithmetic Operators], page 103) and its assignment operator form ‘^=’ (see Section 6.2.3 [Assignment Expressions], page 106).
- C-compatible operator precedence, which breaks some old awk programs (see Section 6.5 [Operator Precedence (How Operators Nest)], page 117).
- Regexps as the value of FS (see Section 4.5 [Specifying How Fields Are Separated], page 62) and as the third argument to the split() function (see Section 9.1.3 [String-Manipulation Functions], page 161), rather than using only the first character of FS.
- Dynamic regexps as operands of the ‘~’ and ‘!~’ operators (see Section 3.1 [How to Use Regular Expressions], page 43).

- The escape sequences '\b', '\f', and '\r' (see Section 3.2 [Escape Sequences], page 44). (Some vendors have updated their old versions of awk to recognize '\b', '\f', and '\r', but this is not something you can rely on.)
- Redirection of input for the getline function (see Section 4.9 [Explicit Input with getline], page 73).
- Multiple BEGIN and END rules (see Section 7.1.4 [The BEGIN and END Special Patterns], page 122).
- Multidimensional arrays (see Section 8.5 [Multidimensional Arrays], page 154).

A.2 Changes Between SVR3.1 and SVR4

The System V Release 4 (1989) version of Unix awk added these features (some of which originated in gawk):

- The ENVIRON array (see Section 7.5 [Built-in Variables], page 134).
- Multiple -f options on the command line (see Section 2.2 [Command-Line Options], page 29).
- The -v option for assigning variables before program execution begins (see Section 2.2 [Command-Line Options], page 29).
- The -- option for terminating command-line options.
- The '\a', '\v', and '\x' escape sequences (see Section 3.2 [Escape Sequences], page 44).
- A defined return value for the srand() built-in function (see Section 9.1.2 [Numeric Functions], page 159).
- The toupper() and tolower() built-in string functions for case translation (see Section 9.1.3 [String-Manipulation Functions], page 161).
- A cleaner specification for the '%c' format-control letter in the printf function (see Section 5.5.2 [Format-Control Letters], page 84).
- The ability to dynamically pass the field width and precision ("%*.*d") in the argument list of the printf function (see Section 5.5.2 [Format-Control Letters], page 84).
- The use of regexp constants, such as /foo/, as expressions, where they are equivalent to using the matching operator, as in '$0 ~ /foo/' (see Section 6.1.2 [Using Regular Expression Constants], page 99).
- Processing of escape sequences inside command-line variable assignments (see Section 6.1.3.2 [Assigning Variables on the Command Line], page 100).

A.3 Changes Between SVR4 and POSIX awk

The POSIX Command Language and Utilities standard for awk (1992) introduced the following changes into the language:

- The use of -W for implementation-specific options (see Section 2.2 [Command-Line Options], page 29).
- The use of CONVFMT for controlling the conversion of numbers to strings (see Section 6.1.4 [Conversion of Strings and Numbers], page 101).
- The concept of a numeric string and tighter comparison rules to go with it (see Section 6.3.2 [Variable Typing and Comparison Expressions], page 110).

- The use of built-in variables as function parameter names is forbidden (see Section 9.2.1 [Function Definition Syntax], page 184.
- More complete documentation of many of the previously undocumented features of the language.

In 2012, a number of extensions that had been commonly available for many years were finally added to POSIX. They are:

- The `fflush()` built-in function for flushing buffered output (see Section 9.1.4 [Input/Output Functions], page 173).
- The `nextfile` statement (see Section 7.4.9 [The `nextfile` Statement], page 133).
- The ability to delete all of an array at once with '`delete` *`array`*' (see Section 8.2 [The `delete` Statement], page 151).

See Section A.6 [Common Extensions Summary], page 393, for a list of common extensions not permitted by the POSIX standard.

The 2008 POSIX standard can be found online at `http://www.opengroup.org/onlinepubs/9699919799/`.

A.4 Extensions in Brian Kernighan's awk

Brian Kernighan has made his version available via his home page (see Section B.5 [Other Freely Available `awk` Implementations], page 412).

This section describes common extensions that originally appeared in his version of `awk`.

- The '`**`' and '`**=`' operators (see Section 6.2.1 [Arithmetic Operators], page 103 and Section 6.2.3 [Assignment Expressions], page 106).
- The use of `func` as an abbreviation for `function` (see Section 9.2.1 [Function Definition Syntax], page 184).
- The `fflush()` built-in function for flushing buffered output (see Section 9.1.4 [Input/Output Functions], page 173).

See Section A.6 [Common Extensions Summary], page 393, for a full list of the extensions available in his `awk`.

A.5 Extensions in gawk Not in POSIX awk

The GNU implementation, `gawk`, adds a large number of features. They can all be disabled with either the `--traditional` or `--posix` options (see Section 2.2 [Command-Line Options], page 29).

A number of features have come and gone over the years. This section summarizes the additional features over POSIX `awk` that are in the current version of `gawk`.

- Additional built-in variables:
  - The `ARGIND` `BINMODE`, `ERRNO`, `FIELDWIDTHS`, `FPAT`, `IGNORECASE`, `LINT`, `PROCINFO`, `RT`, and `TEXTDOMAIN` variables (see Section 7.5 [Built-in Variables], page 134).
- Special files in I/O redirections:
  - The `/dev/stdin`, `/dev/stdout`, `/dev/stderr` and `/dev/fd/N` special file names (see Section 5.7 [Special File Names in `gawk`], page 92).

  - The /inet, /inet4, and '/inet6' special files for TCP/IP networking using '|&' to specify which version of the IP protocol to use. (see Section 12.4 [Using gawk for Network Programming], page 285).
- Changes and/or additions to the language:
  - The '\x' escape sequence (see Section 3.2 [Escape Sequences], page 44).
  - Full support for both POSIX and GNU regexps (see Chapter 3 [Regular Expressions], page 43).
  - The ability for FS and for the third argument to split() to be null strings (see Section 4.5.3 [Making Each Character a Separate Field], page 64).
  - The ability for RS to be a regexp (see Section 4.1 [How Input Is Split into Records], page 55).
  - The ability to use octal and hexadecimal constants in awk program source code (see Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97).
  - The '|&' operator for two-way I/O to a coprocess (see Section 12.3 [Two-Way Communications with Another Process], page 283).
  - Indirect function calls (see Section 9.3 [Indirect Function Calls], page 193).
  - Directories on the command line produce a warning and are skipped (see Section 4.11 [Directories On The Command Line], page 80).
- New keywords:
  - The BEGINFILE and ENDFILE special patterns. (see Section 7.1.5 [The BEGINFILE and ENDFILE Special Patterns], page 123).
  - The ability to delete all of an array at once with '**delete** *array*' (see Section 8.2 [The delete Statement], page 151).
  - The nextfile statement (see Section 7.4.9 [The nextfile Statement], page 133).
  - The switch statement (see Section 7.4.5 [The switch Statement], page 129).
- Changes to standard awk functions:
  - The optional second argument to close() that allows closing one end of a two-way pipe to a coprocess (see Section 12.3 [Two-Way Communications with Another Process], page 283).
  - POSIX compliance for gsub() and sub().
  - The length() function accepts an array argument and returns the number of elements in the array (see Section 9.1.3 [String-Manipulation Functions], page 161).
  - The optional third argument to the match() function for capturing text-matching subexpressions within a regexp (see Section 9.1.3 [String-Manipulation Functions], page 161).
  - Positional specifiers in printf formats for making translations easier (see Section 13.4.2 [Rearranging printf Arguments], page 295).
  - The split() function's additional optional fourth argument which is an array to hold the text of the field separators. (see Section 9.1.3 [String-Manipulation Functions], page 161).
- Additional functions only in gawk:

- The and(), compl(), lshift(), or(), rshift(), and xor() functions for bit manipulation (see Section 9.1.6 [Bit-Manipulation Functions], page 181).
- The asort() and asorti() functions for sorting arrays (see Section 12.2 [Controlling Array Traversal and Array Sorting], page 278).
- The bindtextdomain(), dcgettext() and dcngettext() functions for internationalization (see Section 13.3 [Internationalizing awk Programs], page 293).
- The fflush() function from Brian Kernighan's version of awk (see Section 9.1.4 [Input/Output Functions], page 173).
- The gensub(), patsplit(), and strtonum() functions for more powerful text manipulation (see Section 9.1.3 [String-Manipulation Functions], page 161).
- The mktime(), systime(), and strftime() functions for working with timestamps (see Section 9.1.5 [Time Functions], page 176).

- Changes and/or additions in the command-line options:
  - The AWKPATH environment variable for specifying a path search for the -f command-line option (see Section 2.2 [Command-Line Options], page 29).
  - The AWKLIBPATH environment variable for specifying a path search for the -l command-line option (see Section 2.2 [Command-Line Options], page 29).
  - The -b, -c, -C, -d, -D, -e, -E, -g, -h, -i, -l, -L, -M, -n, -N, -o, -O, -p, -P, -r, -S, -t, and -V short options. Also, the ability to use GNU-style long-named options that start with -- and the --assign, --bignum, --characters-as-bytes, --copyright, --debug, --dump-variables, --execle, --field-separator, --file, --gen-pot, --help, --include, --lint, --lint-old, --load, --non-decimal-data, --optimize, --posix, --pretty-print, --profile, --re-interval, --sandbox, --source, --traditional, --use-lc-numeric, and --version long options (see Section 2.2 [Command-Line Options], page 29).
- Support for the following obsolete systems was removed from the code and the documentation for gawk version 4.0:
  - Amiga
  - Atari
  - BeOS
  - Cray
  - MIPS RiscOS
  - MS-DOS with the Microsoft Compiler
  - MS-Windows with the Microsoft Compiler
  - NeXT
  - SunOS 3.x, Sun 386 (Road Runner)
  - Tandem (non-POSIX)
  - Prestandard VAX C compiler for VAX/VMS

A.6 Common Extensions Summary

This section summarizes the common extensions supported by gawk, Brian Kernighan's awk, and mawk, the three most widely-used freely available versions of awk (see Section B.5 [Other Freely Available awk Implementations], page 412).

Feature	**BWK Awk**	**Mawk**	**GNU Awk**
'\x' Escape sequence	X	X	X
RS as regexp		X	X
FS as null string	X	X	X
/dev/stdin special file	X		X
/dev/stdout special file	X	X	X
/dev/stderr special file	X	X	X
** and **= operators	X		X
fflush() function	X	X	X
func keyword	X		X
nextfile statement	X	X	X
delete without subscript	X	X	X
length() of an array	X		X
BINMODE variable		X	X
Time related functions		X	X

(Technically speaking, as of late 2012, `fflush()`, '`delete` *array*', and `nextfile` are no longer extensions, since they have been added to POSIX.)

A.7 Regexp Ranges and Locales: A Long Sad Story

This section describes the confusing history of ranges within regular expressions and their interactions with locales, and how this affected different versions of `gawk`.

The original Unix tools that worked with regular expressions defined character ranges (such as '`[a-z]`') to match any character between the first character in the range and the last character in the range, inclusive. Ordering was based on the numeric value of each character in the machine's native character set. Thus, on ASCII-based systems, `[a-z]` matched all the lowercase letters, and only the lowercase letters, since the numeric values for the letters from '`a`' through '`z`' were contiguous. (On an EBCDIC system, the range '`[a-z]`' includes additional, non-alphabetic characters as well.)

Almost all introductory Unix literature explained range expressions as working in this fashion, and in particular, would teach that the "correct" way to match lowercase letters was with '`[a-z]`', and that '`[A-Z]`' was the "correct" way to match uppercase letters. And indeed, this was true.[1]

The 1993 POSIX standard introduced the idea of locales (see Section 6.6 [Where You Are Makes A Difference], page 118). Since many locales include other letters besides the plain twenty-six letters of the American English alphabet, the POSIX standard added character classes (see Section 3.4 [Using Bracket Expressions], page 49) as a way to match different kinds of characters besides the traditional ones in the ASCII character set.

However, the standard *changed* the interpretation of range expressions. In the `"C"` and `"POSIX"` locales, a range expression like '`[a-dx-z]`' is still equivalent to '`[abcdxyz]`', as in ASCII. But outside those locales, the ordering was defined to be based on *collation order*.

In many locales, '`A`' and '`a`' are both less than '`B`'. In other words, these locales sort characters in dictionary order, and '`[a-dx-z]`' is typically not equivalent to '`[abcdxyz]`'; instead it might be equivalent to '`[ABCXYabcdxyz]`', for example.

[1] And Life was good.

This point needs to be emphasized: Much literature teaches that you should use '[a-z]' to match a lowercase character. But on systems with non-ASCII locales, this also matched all of the uppercase characters except 'A' or 'Z'! This was a continuous cause of confusion, even well into the twenty-first century.

To demonstrate these issues, the following example uses the sub() function, which does text replacement (see Section 9.1.3 [String-Manipulation Functions], page 161). Here, the intent is to remove trailing uppercase characters:

```
$ echo something1234abc | gawk-3.1.8 '{ sub("[A-Z]*$", ""); print }'
⊣ something1234a
```

This output is unexpected, since the 'bc' at the end of 'something1234abc' should not normally match '[A-Z]*'. This result is due to the locale setting (and thus you may not see it on your system).

Similar considerations apply to other ranges. For example, '["-/]' is perfectly valid in ASCII, but is not valid in many Unicode locales, such as 'en_US.UTF-8'.

Early versions of gawk used regexp matching code that was not locale aware, so ranges had their traditional interpretation.

When gawk switched to using locale-aware regexp matchers, the problems began; especially as both GNU/Linux and commercial Unix vendors started implementing non-ASCII locales, *and making them the default*. Perhaps the most frequently asked question became something like "why does [A-Z] match lowercase letters?!?"

This situation existed for close to 10 years, if not more, and the gawk maintainer grew weary of trying to explain that gawk was being nicely standards-compliant, and that the issue was in the user's locale. During the development of version 4.0, he modified gawk to always treat ranges in the original, pre-POSIX fashion, unless --posix was used (see Section 2.2 [Command-Line Options], page 29).[2]

Fortunately, shortly before the final release of gawk 4.0, the maintainer learned that the 2008 standard had changed the definition of ranges, such that outside the "C" and "POSIX" locales, the meaning of range expressions was *undefined*.[3]

By using this lovely technical term, the standard gives license to implementors to implement ranges in whatever way they choose. The gawk maintainer chose to apply the pre-POSIX meaning in all cases: the default regexp matching; with --traditional, and with --posix; in all cases, gawk remains POSIX compliant.

A.8 Major Contributors to gawk

Always give credit where credit is due.
Anonymous

This section names the major contributors to gawk and/or this book, in approximate chronological order:

---

[2] And thus was born the Campain for Rational Range Interpretation (or RRI). A number of GNU tools, such as grep and sed, have either implemented this change, or will soon. Thanks to Karl Berry for coining the phrase "Rational Range Interpretation."

[3] See the standard (http://pubs.opengroup.org/onlinepubs/9699919799/basedefs/V1_chap09.html#tag_09_03_05) and its rationale (http://pubs.opengroup.org/onlinepubs/9699919799/xrat/V4_xbd_chap09.html#tag_21_09_03_05).

- Dr. Alfred V. Aho, Dr. Peter J. Weinberger, and Dr. Brian W. Kernighan, all of Bell Laboratories, designed and implemented Unix `awk`, from which `gawk` gets the majority of its feature set.
- Paul Rubin did the initial design and implementation in 1986, and wrote the first draft (around 40 pages) of this book.
- Jay Fenlason finished the initial implementation.
- Diane Close revised the first draft of this book, bringing it to around 90 pages.
- Richard Stallman helped finish the implementation and the initial draft of this book. He is also the founder of the FSF and the GNU project.
- John Woods contributed parts of the code (mostly fixes) in the initial version of `gawk`.
- In 1988, David Trueman took over primary maintenance of `gawk`, making it compatible with "new" `awk`, and greatly improving its performance.
- Conrad Kwok, Scott Garfinkle, and Kent Williams did the initial ports to MS-DOS with various versions of MSC.
- Pat Rankin provided the VMS port and its documentation.
- Hal Peterson provided help in porting `gawk` to Cray systems. (This is no longer supported.)
- Kai Uwe Rommel provided the initial port to OS/2 and its documentation.
- Michal Jaegermann provided the port to Atari systems and its documentation. (This port is no longer supported.) He continues to provide portability checking with DEC Alpha systems, and has done a lot of work to make sure `gawk` works on non-32-bit systems.
- Fred Fish provided the port to Amiga systems and its documentation. (With Fred's sad passing, this is no longer supported.)
- Scott Deifik currently maintains the MS-DOS port using DJGPP.
- Eli Zaretskii currently maintains the MS-Windows port using MinGW.
- Juan Grigera provided a port to Windows32 systems. (This is no longer supported.)
- For many years, Dr. Darrel Hankerson acted as coordinator for the various ports to different PC platforms and created binary distributions for various PC operating systems. He was also instrumental in keeping the documentation up to date for the various PC platforms.
- Christos Zoulas provided the `extension()` built-in function for dynamically adding new modules. (This was obsoleted at `gawk` 4.1.)
- Jürgen Kahrs contributed the initial version of the TCP/IP networking code and documentation, and motivated the inclusion of the '`|&`' operator.
- Stephen Davies provided the initial port to Tandem systems and its documentation. (However, this is no longer supported.) He was also instrumental in the initial work to integrate the byte-code internals into the `gawk` code base.
- Matthew Woehlke provided improvements for Tandem's POSIX-compliant systems.
- Martin Brown provided the port to BeOS and its documentation. (This is no longer supported.)
- Arno Peters did the initial work to convert `gawk` to use GNU Automake and GNU `gettext`.

- Alan J. Broder provided the initial version of the `asort()` function as well as the code for the optional third argument to the `match()` function.
- Andreas Buening updated the `gawk` port for OS/2.
- Isamu Hasegawa, of IBM in Japan, contributed support for multibyte characters.
- Michael Benzinger contributed the initial code for `switch` statements.
- Patrick T.J. McPhee contributed the code for dynamic loading in Windows32 environments. (This is no longer supported)
- John Haque made the following contributions:
  - The modifications to convert `gawk` into a byte-code interpreter, including the debugger.
  - The addition of true multidimensional arrays. Section 8.6 [Arrays of Arrays], page 156.
  - The additional modifications for support of arbitrary precision arithmetic.
  - The initial text of Chapter 15 [Arithmetic and Arbitrary Precision Arithmetic with gawk], page 317.
  - The work to merge the three versions of `gawk` into one, for the 4.1 release.
  - Improved array internals for arrays indexed by integers.
  - The improved array sorting features were driven by John together with Pat Rankin.
- Efraim Yawitz contributed the original text for Chapter 14 [Debugging awk Programs], page 301.
- The development of the extension API first released with `gawk` 4.1 was driven primarily by Arnold Robbins and Andrew Schorr, with notable contributions from the rest of the development team.
- Arnold Robbins has been working on `gawk` since 1988, at first helping David Trueman, and as the primary maintainer since around 1994.

Appendix B Installing gawk

This appendix provides instructions for installing gawk on the various platforms that are supported by the developers. The primary developer supports GNU/Linux (and Unix), whereas the other ports are contributed. See Section B.4 [Reporting Problems and Bugs], page 410, for the electronic mail addresses of the people who did the respective ports.

B.1 The gawk Distribution

This section describes how to get the gawk distribution, how to extract it, and then what is in the various files and subdirectories.

B.1.1 Getting the gawk Distribution

There are three ways to get GNU software:

- Copy it from someone else who already has it.
- Retrieve gawk from the Internet host ftp.gnu.org, in the directory /gnu/gawk. Both anonymous ftp and http access are supported. If you have the wget program, you can use a command like the following:

```
wget http://ftp.gnu.org/gnu/gawk/gawk-4.1.0.tar.gz
```

The GNU software archive is mirrored around the world. The up-to-date list of mirror sites is available from the main FSF web site (http://www.gnu.org/order/ftp.html). Try to use one of the mirrors; they will be less busy, and you can usually find one closer to your site.

B.1.2 Extracting the Distribution

gawk is distributed as several tar files compressed with different compression programs: gzip, bzip2, and xz. For simplicity, the rest of these instructions assume you are using the one compressed with the GNU Zip program, gzip.

Once you have the distribution (for example, gawk-4.1.0.tar.gz), use gzip to expand the file and then use tar to extract it. You can use the following pipeline to produce the gawk distribution:

```
# Under System V, add 'o' to the tar options
gzip -d -c gawk-4.1.0.tar.gz | tar -xvpf -
```

On a system with GNU tar, you can let tar do the decompression for you:

```
tar -xvpzf gawk-4.1.0.tar.gz
```

Extracting the archive creates a directory named gawk-4.1.0 in the current directory.

The distribution file name is of the form gawk-*V*.*R*.*P*.tar.gz. The *V* represents the major version of gawk, the *R* represents the current release of version *V*, and the *P* represents a *patch level*, meaning that minor bugs have been fixed in the release. The current patch level is 0, but when retrieving distributions, you should get the version with the highest version, release, and patch level. (Note, however, that patch levels greater than or equal to 70 denote "beta" or nonproduction software; you might not want to retrieve such a version unless you don't mind experimenting.) If you are not on a Unix or GNU/Linux system, you need to make other arrangements for getting and extracting the gawk distribution. You should consult a local expert.

B.1.3 Contents of the gawk Distribution

The gawk distribution has a number of C source files, documentation files, subdirectories, and files related to the configuration process (see Section B.2 [Compiling and Installing gawk on Unix-like Systems], page 402), as well as several subdirectories related to different non-Unix operating systems:

Various '.c', '.y', and '.h' files
: The actual gawk source code.

ABOUT-NLS
: Information about GNU gettext and translations.

AUTHORS
: A file with some information about the authorship of gawk. It exists only to satisfy the pedants at the Free Software Foundation.

README
README_d/README.*
: Descriptive files: README for gawk under Unix and the rest for the various hardware and software combinations.

INSTALL
: A file providing an overview of the configuration and installation process.

ChangeLog
: A detailed list of source code changes as bugs are fixed or improvements made.

ChangeLog.0
: An older list of source code changes.

NEWS
: A list of changes to gawk since the last release or patch.

NEWS.0
: An older list of changes to gawk.

COPYING
: The GNU General Public License.

POSIX.STD
: A description of behaviors in the POSIX standard for awk which are left undefined, or where gawk may not comply fully, as well as a list of things that the POSIX standard should describe but does not.

doc/awkforai.txt
: Pointers to the original draft of a short article describing why gawk is a good language for Artificial Intelligence (AI) programming.

doc/bc_notes
: A brief description of gawk's "byte code" internals.

`doc/README.card`
`doc/ad.block`
`doc/awkcard.in`
`doc/cardfonts`
`doc/colors`
`doc/macros`
`doc/no.colors`
`doc/setter.outline`

The `troff` source for a five-color `awk` reference card. A modern version of `troff` such as GNU `troff` (`groff`) is needed to produce the color version. See the file `README.card` for instructions if you have an older `troff`.

`doc/gawk.1`

The `troff` source for a manual page describing `gawk`. This is distributed for the convenience of Unix users.

`doc/gawktexi.in`
`doc/sidebar.awk`

The Texinfo source file for this book. It should be processed by `doc/sidebar.awk` before processing with `texi2dvi` or `texi2pdf` to produce a printed document, and with `makeinfo` to produce an Info or HTML file. The `Makefile` takes care of this processing and produces printable output via `texi2dvi` or `texi2pdf`.

`doc/gawk.texi`

The file produced after processing `gawktexi.in` with `sidebar.awk`.

`doc/gawk.info`

The generated Info file for this book.

`doc/gawkinet.texi`

The Texinfo source file for *TCP/IP Internetworking with* `gawk`. It should be processed with TeX (via `texi2dvi` or `texi2pdf`) to produce a printed document and with `makeinfo` to produce an Info or HTML file.

`doc/gawkinet.info`

The generated Info file for *TCP/IP Internetworking with* `gawk`.

`doc/igawk.1`

The `troff` source for a manual page describing the `igawk` program presented in Section 11.3.9 [An Easy Way to Use Library Functions], page 266.

`doc/Makefile.in`

The input file used during the configuration process to generate the actual `Makefile` for creating the documentation.

`Makefile.am`
`*/Makefile.am`

Files used by the GNU `automake` software for generating the `Makefile.in` files used by `autoconf` and `configure`.

`Makefile.in`
`aclocal.m4`
`bisonfix.awk`
`config.guess`
`configh.in`
`configure.ac`
`configure`
`custom.h`
`depcomp`
`install-sh`
`missing_d/*`
`mkinstalldirs`
`m4/*` These files and subdirectories are used when configuring and compiling `gawk` for various Unix systems. Most of them are explained in Section B.2 [Compiling and Installing `gawk` on Unix-like Systems], page 402. The rest are there to support the main infrastructure.

`po/*` The `po` library contains message translations.

`awklib/extract.awk`
`awklib/Makefile.am`
`awklib/Makefile.in`
`awklib/eg/*`
The `awklib` directory contains a copy of `extract.awk` (see Section 11.3.7 [Extracting Programs from Texinfo Source Files], page 261), which can be used to extract the sample programs from the Texinfo source file for this book. It also contains a `Makefile.in` file, which `configure` uses to generate a `Makefile`. `Makefile.am` is used by GNU Automake to create `Makefile.in`. The library functions from Chapter 10 [A Library of `awk` Functions], page 201, and the `igawk` program from Section 11.3.9 [An Easy Way to Use Library Functions], page 266, are included as ready-to-use files in the `gawk` distribution. They are installed as part of the installation process. The rest of the programs in this book are available in appropriate subdirectories of `awklib/eg`.

`posix/*` Files needed for building `gawk` on POSIX-compliant systems.

`pc/*` Files needed for building `gawk` under MS-Windows and OS/2 (see Section B.3.1 [Installation on PC Operating Systems], page 405, for details).

`vms/*` Files needed for building `gawk` under VMS (see Section B.3.2 [How to Compile and Install `gawk` on VMS], page 409, for details).

`test/*` A test suite for `gawk`. You can use '`make check`' from the top-level `gawk` directory to run your version of `gawk` against the test suite. If `gawk` successfully passes '`make check`', then you can be confident of a successful port.

B.2 Compiling and Installing gawk on Unix-like Systems

Usually, you can compile and install `gawk` by typing only two commands. However, if you use an unusual system, you may need to configure `gawk` for your system yourself.

B.2.1 Compiling gawk for Unix-like Systems

The normal installation steps should work on all modern commercial Unix-derived systems, GNU/Linux, BSD-based systems, and the Cygwin environment for MS-Windows.

After you have extracted the gawk distribution, cd to gawk-4.1.0. Like most GNU software, gawk is configured automatically for your system by running the configure program. This program is a Bourne shell script that is generated automatically using GNU autoconf. (The autoconf software is described fully in *Autoconf—Generating Automatic Configuration Scripts*, which can be found online at the Free Software Foundation's web site (http://www.gnu.org/software/autoconf/manual/index.html).)

To configure gawk, simply run configure:

```
sh ./configure
```

This produces a Makefile and config.h tailored to your system. The config.h file describes various facts about your system. You might want to edit the Makefile to change the CFLAGS variable, which controls the command-line options that are passed to the C compiler (such as optimization levels or compiling for debugging).

Alternatively, you can add your own values for most make variables on the command line, such as CC and CFLAGS, when running configure:

```
CC=cc CFLAGS=-g sh ./configure
```

See the file INSTALL in the gawk distribution for all the details.

After you have run configure and possibly edited the Makefile, type:

```
make
```

Shortly thereafter, you should have an executable version of gawk. That's all there is to it! To verify that gawk is working properly, run 'make check'. All of the tests should succeed. If these steps do not work, or if any of the tests fail, check the files in the README_d directory to see if you've found a known problem. If the failure is not described there, please send in a bug report (see Section B.4 [Reporting Problems and Bugs], page 410).

Of course, once you've built gawk, it is likely that you will wish to install it. To do so, you need to run the command 'make check', as a user with the appropriate permissions. How to do this varies by system, but on many systems you can use the sudo command to do so. The command then becomes 'sudo make install'. It is likely that you will be asked for your password, and you will have to have been set up previously as a user who is allowed to run the sudo command.

B.2.2 Additional Configuration Options

There are several additional options you may use on the configure command line when compiling gawk from scratch, including:

--disable-lint
: Disable all lint checking within gawk. The --lint and --lint-old options (see Section 2.2 [Command-Line Options], page 29) are accepted, but silently do nothing. Similarly, setting the LINT variable (see Section 7.5.1 [Built-in Variables That Control awk], page 135) has no effect on the running awk program.

  When used with GCC's automatic dead-code-elimination, this option cuts almost 200K bytes off the size of the gawk executable on GNU/Linux x86 systems.

Results on other systems and with other compilers are likely to vary. Using this option may bring you some slight performance improvement.

Using this option will cause some of the tests in the test suite to fail. This option may be removed at a later date.

`--disable-nls`
: Disable all message-translation facilities. This is usually not desirable, but it may bring you some slight performance improvement.

`--with-whiny-user-strftime`
: Force use of the included version of the `strftime()` function for deficient systems.

Use the command '`./configure --help`' to see the full list of options that `configure` supplies.

B.2.3 The Configuration Process

This section is of interest only if you know something about using the C language and Unix-like operating systems.

The source code for `gawk` generally attempts to adhere to formal standards wherever possible. This means that `gawk` uses library routines that are specified by the ISO C standard and by the POSIX operating system interface standard. The `gawk` source code requires using an ISO C compiler (the 1990 standard).

Many Unix systems do not support all of either the ISO or the POSIX standards. The `missing_d` subdirectory in the `gawk` distribution contains replacement versions of those functions that are most likely to be missing.

The `config.h` file that `configure` creates contains definitions that describe features of the particular operating system where you are attempting to compile `gawk`. The three things described by this file are: what header files are available, so that they can be correctly included, what (supposedly) standard functions are actually available in your C libraries, and various miscellaneous facts about your operating system. For example, there may not be an `st_blksize` element in the `stat` structure. In this case, '`HAVE_STRUCT_STAT_ST_BLKSIZE`' is undefined.

It is possible for your C compiler to lie to `configure`. It may do so by not exiting with an error when a library function is not available. To get around this, edit the file `custom.h`. Use an '`#ifdef`' that is appropriate for your system, and either `#define` any constants that `configure` should have defined but didn't, or `#undef` any constants that `configure` defined and should not have. `custom.h` is automatically included by `config.h`.

It is also possible that the `configure` program generated by `autoconf` will not work on your system in some other fashion. If you do have a problem, the file `configure.ac` is the input for `autoconf`. You may be able to change this file and generate a new version of `configure` that works on your system (see Section B.4 [Reporting Problems and Bugs], page 410, for information on how to report problems in configuring `gawk`). The same mechanism may be used to send in updates to `configure.ac` and/or `custom.h`.

B.3 Installation on Other Operating Systems

This section describes how to install `gawk` on various non-Unix systems.

B.3.1 Installation on PC Operating Systems

This section covers installation and usage of gawk on x86 machines running MS-DOS, any version of MS-Windows, or OS/2. In this section, the term "Windows32" refers to any of Microsoft Windows-95/98/ME/NT/2000/XP/Vista/7.

The limitations of MS-DOS (and MS-DOS shells under Windows32 or OS/2) has meant that various "DOS extenders" are often used with programs such as gawk. The varying capabilities of Microsoft Windows 3.1 and Windows32 can add to the confusion. For an overview of the considerations, please refer to README_d/README.pc in the distribution.

B.3.1.1 Installing a Prepared Distribution for PC Systems

If you have received a binary distribution prepared by the MS-DOS maintainers, then gawk and the necessary support files appear under the gnu directory, with executables in gnu/bin, libraries in gnu/lib/awk, and manual pages under gnu/man. This is designed for easy installation to a /gnu directory on your drive—however, the files can be installed anywhere provided AWKPATH is set properly. Regardless of the installation directory, the first line of igawk.cmd and igawk.bat (in gnu/bin) may need to be edited.

The binary distribution contains a separate file describing the contents. In particular, it may include more than one version of the gawk executable.

OS/2 (32 bit, EMX) binary distributions are prepared for the /usr directory of your preferred drive. Set UNIXROOT to your installation drive (e.g., 'e:') if you want to install gawk onto another drive than the hardcoded default 'c:'. Executables appear in /usr/bin, libraries under /usr/share/awk, manual pages under /usr/man, Texinfo documentation under /usr/info, and NLS files under /usr/share/locale. Note that the files can be installed anywhere provided AWKPATH is set properly.

If you already have a file /usr/info/dir from another package *do not overwrite it!* Instead enter the following commands at your prompt (replace 'x:' by your installation drive):

```
install-info --info-dir=x:/usr/info x:/usr/info/gawk.info
install-info --info-dir=x:/usr/info x:/usr/info/gawkinet.info
```

The binary distribution may contain a separate file containing additional or more detailed installation instructions.

B.3.1.2 Compiling gawk for PC Operating Systems

gawk can be compiled for MS-DOS, Windows32, and OS/2 using the GNU development tools from DJ Delorie (DJGPP: MS-DOS only) or Eberhard Mattes (EMX: MS-DOS, Windows32 and OS/2). The file README_d/README.pc in the gawk distribution contains additional notes, and pc/Makefile contains important information on compilation options.

To build gawk for MS-DOS and Windows32, copy the files in the pc directory (*except* for ChangeLog) to the directory with the rest of the gawk sources, then invoke make with the appropriate target name as an argument to build gawk. The Makefile copied from the pc directory contains a configuration section with comments and may need to be edited in order to work with your make utility.

The Makefile supports a number of targets for building various MS-DOS and Windows32 versions. A list of targets is printed if the make command is given without a target.

As an example, to build `gawk` using the DJGPP tools, enter '`make djgpp`'. (The DJGPP tools needed for the build may be found at `ftp://ftp.delorie.com/pub/djgpp/current/v2gnu/`.) To build a native MS-Windows binary of `gawk`, type '`make mingw32`'.

The 32 bit EMX version of `gawk` works "out of the box" under OS/2. However, it is highly recommended to use GCC 2.95.3 for the compilation. In principle, it is possible to compile `gawk` the following way:

```
$ ./configure
$ make
```

This is not recommended, though. To get an OMF executable you should use the following commands at your `sh` prompt:

```
$ CFLAGS="-O2 -Zomf -Zmt"
$ export CFLAGS
$ LDFLAGS="-s -Zcrtdll -Zlinker /exepack:2 -Zlinker /pm:vio -Zstack 0x6000"
$ export LDFLAGS
$ RANLIB="echo"
$ export RANLIB
$ ./configure --prefix=c:/usr
$ make AR=emxomfar
```

These are just suggestions for use with GCC 2.x. You may use any other set of (self-consistent) environment variables and compiler flags.

If you use GCC 2.95 it is recommended to use also:

```
$ LIBS="-lgcc"
$ export LIBS
```

You can also get an `a.out` executable if you prefer:

```
$ CFLAGS="-O2 -Zmt"
$ export CFLAGS
$ LDFLAGS="-s -Zstack 0x6000"
$ LIBS="-lgcc"
$ unset RANLIB
$ ./configure --prefix=c:/usr
$ make
```

> **NOTE:** Compilation of `a.out` executables also works with GCC 3.2. Versions later than GCC 3.2 have not been tested successfully.

'`make install`' works as expected with the EMX build.

> **NOTE:** Ancient OS/2 ports of GNU `make` are not able to handle the Makefiles of this package. If you encounter any problems with `make`, try GNU Make 3.79.1 or later versions. You should find the latest version on `ftp://hobbes.nmsu.edu/pub/os2/`.

B.3.1.3 Testing gawk on PC Operating Systems

Using `make` to run the standard tests and to install `gawk` requires additional Unix-like tools, including `sh`, `sed`, and `cp`. In order to run the tests, the `test/*.ok` files may need to be converted so that they have the usual MS-DOS-style end-of-line markers. Alternatively, run `make check CMP="diff -a"` to use GNU `diff` in text mode instead of `cmp` to compare the resulting files.

Most of the tests work properly with Stewartson's shell along with the companion utilities or appropriate GNU utilities. However, some editing of `test/Makefile` is required. It is recommended that you copy the file `pc/Makefile.tst` over the file `test/Makefile` as a replacement. Details can be found in `README_d/README.pc` and in the file `pc/Makefile.tst`.

On OS/2 the `pid` test fails because `spawnl()` is used instead of `fork()`/`execl()` to start child processes. Also the `mbfw1` and `mbprintf1` tests fail because the needed multibyte functionality is not available.

B.3.1.4 Using gawk on PC Operating Systems

With the exception of the Cygwin environment, the '`|&`' operator and TCP/IP networking (see Section 12.4 [Using `gawk` for Network Programming], page 285) are not supported for MS-DOS or MS-Windows. EMX (OS/2 only) does support at least the '`|&`' operator.

The MS-DOS and MS-Windows versions of `gawk` search for program files as described in Section 2.5.1 [The `AWKPATH` Environment Variable], page 36. However, semicolons (rather than colons) separate elements in the `AWKPATH` variable. If `AWKPATH` is not set or is empty, then the default search path for MS-Windows and MS-DOS versions is `".;c:/lib/awk;c:/gnu/lib/awk"`.

The search path for OS/2 (32 bit, EMX) is determined by the prefix directory (most likely `/usr` or `c:/usr`) that has been specified as an option of the `configure` script like it is the case for the Unix versions. If `c:/usr` is the prefix directory then the default search path contains `.` and `c:/usr/share/awk`. Additionally, to support binary distributions of `gawk` for OS/2 systems whose drive '`c:`' might not support long file names or might not exist at all, there is a special environment variable. If `UNIXROOT` specifies a drive then this specific drive is also searched for program files. E.g., if `UNIXROOT` is set to `e:` the complete default search path is `".;c:/usr/share/awk;e:/usr/share/awk"`.

An `sh`-like shell (as opposed to `command.com` under MS-DOS or `cmd.exe` under MS-Windows or OS/2) may be useful for `awk` programming. The DJGPP collection of tools includes an MS-DOS port of Bash, and several shells are available for OS/2, including `ksh`.

Under MS-Windows, OS/2 and MS-DOS, `gawk` (and many other text programs) silently translate end-of-line `"\r\n"` to `"\n"` on input and `"\n"` to `"\r\n"` on output. A special `BINMODE` variable (c.e.) allows control over these translations and is interpreted as follows:

- If `BINMODE` is `"r"`, or one, then binary mode is set on read (i.e., no translations on reads).
- If `BINMODE` is `"w"`, or two, then binary mode is set on write (i.e., no translations on writes).
- If `BINMODE` is `"rw"` or `"wr"` or three, binary mode is set for both read and write.
- `BINMODE=`*`non-null-string`* is the same as '`BINMODE=3`' (i.e., no translations on reads or writes). However, `gawk` issues a warning message if the string is not one of `"rw"` or `"wr"`.

The modes for standard input and standard output are set one time only (after the command line is read, but before processing any of the `awk` program). Setting `BINMODE` for standard input or standard output is accomplished by using an appropriate '`-v BINMODE=`*N*' option on the command line. `BINMODE` is set at the time a file or pipe is opened and cannot be changed mid-stream.

The name `BINMODE` was chosen to match `mawk` (see Section B.5 [Other Freely Available `awk` Implementations], page 412). `mawk` and `gawk` handle `BINMODE` similarly; however, `mawk` adds a '`-W BINMODE=N`' option and an environment variable that can set `BINMODE`, `RS`, and `ORS`. The files `binmode[1-3].awk` (under `gnu/lib/awk` in some of the prepared distributions) have been chosen to match `mawk`'s '`-W BINMODE=N`' option. These can be changed or discarded; in particular, the setting of `RS` giving the fewest "surprises" is open to debate. `mawk` uses '`RS = "\r\n"`' if binary mode is set on read, which is appropriate for files with the MS-DOS-style end-of-line.

To illustrate, the following examples set binary mode on writes for standard output and other files, and set `ORS` as the "usual" MS-DOS-style end-of-line:

```
gawk -v BINMODE=2 -v ORS="\r\n" ...
```

or:

```
gawk -v BINMODE=w -f binmode2.awk ...
```

These give the same result as the '`-W BINMODE=2`' option in `mawk`. The following changes the record separator to `"\r\n"` and sets binary mode on reads, but does not affect the mode on standard input:

```
gawk -v RS="\r\n" --source "BEGIN { BINMODE = 1 }" ...
```

or:

```
gawk -f binmode1.awk ...
```

With proper quoting, in the first example the setting of `RS` can be moved into the `BEGIN` rule.

B.3.1.5 Using gawk In The Cygwin Environment

`gawk` can be built and used "out of the box" under MS-Windows if you are using the Cygwin environment (`http://www.cygwin.com`). This environment provides an excellent simulation of Unix, using the GNU tools, such as Bash, the GNU Compiler Collection (GCC), GNU Make, and other GNU programs. Compilation and installation for Cygwin is the same as for a Unix system:

```
tar -xvpzf gawk-4.1.0.tar.gz
cd gawk-4.1.0
./configure
make
```

When compared to GNU/Linux on the same system, the '`configure`' step on Cygwin takes considerably longer. However, it does finish, and then the '`make`' proceeds as usual.

> **NOTE:** The '`|&`' operator and TCP/IP networking (see Section 12.4 [Using `gawk` for Network Programming], page 285) are fully supported in the Cygwin environment. This is not true for any other environment on MS-Windows.

B.3.1.6 Using gawk In The MSYS Environment

In the MSYS environment under MS-Windows, `gawk` automatically uses binary mode for reading and writing files. Thus there is no need to use the `BINMODE` variable.

This can cause problems with other Unix-like components that have been ported to MS-Windows that expect gawk to do automatic translation of "\r\n", since it won't. Caveat Emptor!

B.3.2 How to Compile and Install gawk on VMS

This subsection describes how to compile and install gawk under VMS. The older designation "VMS" is used throughout to refer to OpenVMS.

B.3.2.1 Compiling gawk on VMS

To compile gawk under VMS, there is a DCL command procedure that issues all the necessary CC and LINK commands. There is also a Makefile for use with the MMS utility. From the source directory, use either:

```
$ @[.VMS]VMSBUILD.COM
```

or:

```
$ MMS/DESCRIPTION=[.VMS]DESCRIP.MMS GAWK
```

Older versions of gawk could be built with VAX C or GNU C on VAX/VMS, as well as with DEC C, but that is no longer supported. DEC C (also briefly known as "Compaq C" and now known as "HP C," but referred to here as "DEC C") is required. Both VMSBUILD.COM and DESCRIP.MMS contain some obsolete support for the older compilers but are set up to use DEC C by default.

gawk has been tested under Alpha/VMS 7.3-1 using Compaq C V6.4, and on Alpha/VMS 7.3, Alpha/VMS 7.3-2, and IA64/VMS 8.3.[1]

B.3.2.2 Installing gawk on VMS

To install gawk, all you need is a "foreign" command, which is a DCL symbol whose value begins with a dollar sign. For example:

```
$ GAWK :== $disk1:[gnubin]GAWK
```

Substitute the actual location of gawk.exe for '$disk1:[gnubin]'. The symbol should be placed in the login.com of any user who wants to run gawk, so that it is defined every time the user logs on. Alternatively, the symbol may be placed in the system-wide sylogin.com procedure, which allows all users to run gawk.

Optionally, the help entry can be loaded into a VMS help library:

```
$ LIBRARY/HELP SYS$HELP:HELPLIB [.VMS]GAWK.HLP
```

(You may want to substitute a site-specific help library rather than the standard VMS library 'HELPLIB'.) After loading the help text, the command:

```
$ HELP GAWK
```

provides information about both the gawk implementation and the awk programming language.

The logical name 'AWK_LIBRARY' can designate a default location for awk program files. For the -f option, if the specified file name has no device or directory path information in it, gawk looks in the current directory first, then in the directory specified by the translation of 'AWK_LIBRARY' if the file is not found. If, after searching in both directories, the file still

[1] The IA64 architecture is also known as "Itanium."

is not found, gawk appends the suffix '.awk' to the filename and retries the file search. If 'AWK_LIBRARY' has no definition, a default value of 'SYS$LIBRARY:' is used for it.

B.3.2.3 Running gawk on VMS

Command-line parsing and quoting conventions are significantly different on VMS, so examples in this book or from other sources often need minor changes. They *are* minor though, and all awk programs should run correctly.

Here are a couple of trivial tests:

```
$ gawk -- "BEGIN {print ""Hello, World!""}"
$ gawk -"W" version
! could also be -"W version" or "-W version"
```

Note that uppercase and mixed-case text must be quoted.

The VMS port of gawk includes a DCL-style interface in addition to the original shell-style interface (see the help entry for details). One side effect of dual command-line parsing is that if there is only a single parameter (as in the quoted string program above), the command becomes ambiguous. To work around this, the normally optional -- flag is required to force Unix-style parsing rather than DCL parsing. If any other dash-type options (or multiple parameters such as data files to process) are present, there is no ambiguity and -- can be omitted.

The default search path, when looking for awk program files specified by the -f option, is "SYS$DISK:[],AWK_LIBRARY:". The logical name AWKPATH can be used to override this default. The format of AWKPATH is a comma-separated list of directory specifications. When defining it, the value should be quoted so that it retains a single translation and not a multitranslation RMS searchlist.

B.3.2.4 Some VMS Systems Have An Old Version of gawk

Some versions of VMS have an old version of gawk. To access it, define a symbol, as follows:

```
$ gawk :== $sys$common:[syshlp.examples.tcpip.snmp]gawk.exe
```

This is apparently version 2.15.6, which is extremely old. We recommend compiling and using the current version.

B.4 Reporting Problems and Bugs

> *There is nothing more dangerous than a bored archeologist.*
> The Hitchhiker's Guide to the Galaxy

If you have problems with gawk or think that you have found a bug, please report it to the developers; we cannot promise to do anything but we might well want to fix it.

Before reporting a bug, make sure you have actually found a real bug. Carefully reread the documentation and see if it really says you can do what you're trying to do. If it's not clear whether you should be able to do something or not, report that too; it's a bug in the documentation!

Before reporting a bug or trying to fix it yourself, try to isolate it to the smallest possible awk program and input data file that reproduces the problem. Then send us the program and data file, some idea of what kind of Unix system you're using, the compiler you used to compile `gawk`, and the exact results `gawk` gave you. Also say what you expected to occur; this helps us decide whether the problem is really in the documentation.

Please include the version number of `gawk` you are using. You can get this information with the command '`gawk --version`'.

Once you have a precise problem, send email to `bug-gawk@gnu.org`.

Using this address automatically sends a copy of your mail to me. If necessary, I can be reached directly at `arnold@skeeve.com`. The bug reporting address is preferred since the email list is archived at the GNU Project. *All email should be in English, since that is my native language.*

> **CAUTION:** Do *not* try to report bugs in `gawk` by posting to the Usenet/Internet newsgroup `comp.lang.awk`. While the `gawk` developers do occasionally read this newsgroup, there is no guarantee that we will see your posting. The steps described above are the official recognized ways for reporting bugs. Really.

> **NOTE:** Many distributions of GNU/Linux and the various BSD-based operating systems have their own bug reporting systems. If you report a bug using your distribution's bug reporting system, *please* also send a copy to `bug-gawk@gnu.org`.
>
> This is for two reasons. First, while some distributions forward bug reports "upstream" to the GNU mailing list, many don't, so there is a good chance that the `gawk` maintainer won't even see the bug report! Second, mail to the GNU list is archived, and having everything at the GNU project keeps things self-contained and not dependant on other web sites.

Non-bug suggestions are always welcome as well. If you have questions about things that are unclear in the documentation or are just obscure features, ask me; I will try to help you out, although I may not have the time to fix the problem. You can send me electronic mail at the Internet address noted previously.

If you find bugs in one of the non-Unix ports of `gawk`, please send an electronic mail message to the person who maintains that port. They are named in the following list, as well as in the `README` file in the `gawk` distribution. Information in the `README` file should be considered authoritative if it conflicts with this book.

The people maintaining the non-Unix ports of `gawk` are as follows:

MS-DOS with DJGPP
: Scott Deifik, `scottd.mail@sbcglobal.net`.

MS-Windows with MINGW
: Eli Zaretskii, `eliz@gnu.org`.

OS/2
: Andreas Buening, `andreas.buening@nexgo.de`.

VMS
: Pat Rankin, `r.pat.rankin@gmail.com`

z/OS (OS/390)
: Dave Pitts, `dpitts@cozx.com`.

If your bug is also reproducible under Unix, please send a copy of your report to the `bug-gawk@gnu.org` email list as well.

B.5 Other Freely Available awk Implementations

It's kind of fun to put comments like this in your awk code.
`// Do C++ comments work? answer: yes! of course`
Michael Brennan

There are a number of other freely available `awk` implementations. This section briefly describes where to get them:

Unix `awk`
: Brian Kernighan, one of the original designers of Unix `awk`, has made his implementation of `awk` freely available. You can retrieve this version via the World Wide Web from his home page (`http://www.cs.princeton.edu/~bwk`). It is available in several archive formats:

Shell archive
: `http://www.cs.princeton.edu/~bwk/btl.mirror/awk.shar`

Compressed `tar` file
: `http://www.cs.princeton.edu/~bwk/btl.mirror/awk.tar.gz`

Zip file
: `http://www.cs.princeton.edu/~bwk/btl.mirror/awk.zip`

You can also retrieve it from Git Hub:

```
git clone git://github.com/onetrueawk/awk bwkawk
```

The above command creates a copy of the Git (`http://www.git-scm.com`) repository in a directory named `bwkawk`. If you leave that argument off the `git` command line, the repository copy is created in a directory named `awk`.

This version requires an ISO C (1990 standard) compiler; the C compiler from GCC (the GNU Compiler Collection) works quite nicely.

See Section A.6 [Common Extensions Summary], page 393, for a list of extensions in this `awk` that are not in POSIX `awk`.

`mawk`
: Michael Brennan wrote an independent implementation of `awk`, called `mawk`. It is available under the GPL (see [GNU General Public License], page 439), just as `gawk` is.

The original distribution site for the `mawk` source code no longer has it. A copy is available at `http://www.skeeve.com/gawk/mawk1.3.3.tar.gz`.

In 2009, Thomas Dickey took on `mawk` maintenance. Basic information is available on the project's web page (`http://www.invisible-island.net/mawk`). The download URL is `http://invisible-island.net/datafiles/release/mawk.tar.gz`.

Once you have it, `gunzip` may be used to decompress this file. Installation is similar to `gawk`'s (see Section B.2 [Compiling and Installing `gawk` on Unix-like Systems], page 402).

See Section A.6 [Common Extensions Summary], page 393, for a list of extensions in `mawk` that are not in POSIX `awk`.

`awka`
: Written by Andrew Sumner, `awka` translates `awk` programs into C, compiles them, and links them with a library of functions that provides the core `awk` functionality. It also has a number of extensions.

The awk translator is released under the GPL, and the library is under the LGPL.

To get awka, go to http://sourceforge.net/projects/awka.

The project seems to be frozen; no new code changes have been made since approximately 2003.

pawk
Nelson H.F. Beebe at the University of Utah has modified Brian Kernighan's awk to provide timing and profiling information. It is different from gawk with the --profile option. (see Section 12.5 [Profiling Your awk Programs], page 287), in that it uses CPU-based profiling, not line-count profiling. You may find it at either ftp://ftp.math.utah.edu/pub/pawk/pawk-20030606.tar.gz or http://www.math.utah.edu/pub/pawk/pawk-20030606.tar.gz.

Busybox Awk
Busybox is a GPL-licensed program providing small versions of many applications within a single executable. It is aimed at embedded systems. It includes a full implementation of POSIX awk. When building it, be careful not to do 'make install' as it will overwrite copies of other applications in your /usr/local/bin. For more information, see the project's home page (http://busybox.net).

The OpenSolaris POSIX awk
The version of awk in /usr/xpg4/bin on Solaris is more-or-less POSIX-compliant. It is based on the awk from Mortice Kern Systems for PCs. This author was able to make it compile and work under GNU/Linux with 1–2 hours of work. Making it more generally portable (using GNU Autoconf and/or Automake) would take more work, and this has not been done, at least to our knowledge.

The source code used to be available from the OpenSolaris web site. However, that project was ended and the web site shut down. Fortunately, the Illumos project (http://wiki.illumos.org/display/illumos/illumos+Home) makes this implementation available. You can view the files one at a time from https://github.com/joyent/illumos-joyent/blob/master/usr/src/cmd/awk_xpg4.

jawk
This is an interpreter for awk written in Java. It claims to be a full interpreter, although because it uses Java facilities for I/O and for regexp matching, the language it supports is different from POSIX awk. More information is available on the project's home page (http://jawk.sourceforge.net).

Libmawk
This is an embeddable awk interpreter derived from mawk. For more information see http://repo.hu/projects/libmawk/.

pawk
This is a Python module that claims to bring awk-like features to Python. See https://github.com/alecthomas/pawk for more information. (This is not related to Nelson Beebe's modified version of Brian Kernighan's awk, described earlier.)

QSE Awk
This is an embeddable awk interpreter. For more information see http://code.google.com/p/qse/ and http://awk.info/?tools/qse.

`QTawk` This is an independent implementation of `awk` distributed under the GPL. It has a large number of extensions over standard `awk` and may not be 100% syntactically compatible with it. See `http://www.quiktrim.org/QTawk.html` for more information, including the manual and a download link.

Other Versions
See also the Wikipedia article (`http://en.wikipedia.org/wiki/Awk_language#Versions_and_implementations`), for information on additional versions.

Appendix C Implementation Notes

This appendix contains information mainly of interest to implementers and maintainers of gawk. Everything in it applies specifically to gawk and not to other implementations.

C.1 Downward Compatibility and Debugging

See Section A.5 [Extensions in gawk Not in POSIX awk], page 391, for a summary of the GNU extensions to the awk language and program. All of these features can be turned off by invoking gawk with the --traditional option or with the --posix option.

If gawk is compiled for debugging with '-DDEBUG', then there is one more option available on the command line:

-Y
--parsedebug
Prints out the parse stack information as the program is being parsed.

This option is intended only for serious gawk developers and not for the casual user. It probably has not even been compiled into your version of gawk, since it slows down execution.

C.2 Making Additions to gawk

If you find that you want to enhance gawk in a significant fashion, you are perfectly free to do so. That is the point of having free software; the source code is available and you are free to change it as you want (see [GNU General Public License], page 439).

This section discusses the ways you might want to change gawk as well as any considerations you should bear in mind.

C.2.1 Accessing The gawk Git Repository

As gawk is Free Software, the source code is always available. Section B.1 [The gawk Distribution], page 399, describes how to get and build the formal, released versions of gawk.

However, if you want to modify gawk and contribute back your changes, you will probably wish to work with the development version. To do so, you will need to access the gawk source code repository. The code is maintained using the Git distributed version control system (http://git-scm.com/). You will need to install it if your system doesn't have it. Once you have done so, use the command:

```
git clone git://git.savannah.gnu.org/gawk.git
```

This will clone the gawk repository. If you are behind a firewall that will not allow you to use the Git native protocol, you can still access the repository using:

```
git clone http://git.savannah.gnu.org/r/gawk.git
```

Once you have made changes, you can use 'git diff' to produce a patch, and send that to the gawk maintainer; see Section B.4 [Reporting Problems and Bugs], page 410, for how to do that.

Once upon a time there was Git–CVS gateway for use by people who could not install Git. However, this gateway no longer works, so you may have better luck using a more modern version control system like Bazaar, that has a Git plug-in for working with Git repositories.

C.2.2 Adding New Features

You are free to add any new features you like to gawk. However, if you want your changes to be incorporated into the gawk distribution, there are several steps that you need to take in order to make it possible to include your changes:

1. Before building the new feature into gawk itself, consider writing it as an extension module (see Chapter 16 [Writing Extensions for gawk], page 333). If that's not possible, continue with the rest of the steps in this list.
2. Be prepared to sign the appropriate paperwork. In order for the FSF to distribute your changes, you must either place those changes in the public domain and submit a signed statement to that effect, or assign the copyright in your changes to the FSF. Both of these actions are easy to do and *many* people have done so already. If you have questions, please contact me (see Section B.4 [Reporting Problems and Bugs], page 410), or assign@gnu.org.
3. Get the latest version. It is much easier for me to integrate changes if they are relative to the most recent distributed version of gawk. If your version of gawk is very old, I may not be able to integrate them at all. (See Section B.1.1 [Getting the gawk Distribution], page 399, for information on getting the latest version of gawk.)
4. Follow the *GNU Coding Standards*. This document describes how GNU software should be written. If you haven't read it, please do so, preferably *before* starting to modify gawk. (The *GNU Coding Standards* are available from the GNU Project's web site (http://www.gnu.org/prep/standards_toc.html). Texinfo, Info, and DVI versions are also available.)
5. Use the gawk coding style. The C code for gawk follows the instructions in the *GNU Coding Standards*, with minor exceptions. The code is formatted using the traditional "K&R" style, particularly as regards to the placement of braces and the use of TABs. In brief, the coding rules for gawk are as follows:
   - Use ANSI/ISO style (prototype) function headers when defining functions.
   - Put the name of the function at the beginning of its own line.
   - Put the return type of the function, even if it is `int`, on the line above the line with the name and arguments of the function.
   - Put spaces around parentheses used in control structures (`if`, `while`, `for`, `do`, `switch`, and `return`).
   - Do not put spaces in front of parentheses used in function calls.
   - Put spaces around all C operators and after commas in function calls.
   - Do not use the comma operator to produce multiple side effects, except in `for` loop initialization and increment parts, and in macro bodies.
   - Use real TABs for indenting, not spaces.
   - Use the "K&R" brace layout style.
   - Use comparisons against `NULL` and `'\0'` in the conditions of `if`, `while`, and `for` statements, as well as in the `case`s of `switch` statements, instead of just the plain pointer or character value.

- Use `true` and `false` for `bool` values, the `NULL` symbolic constant for pointer values, and the character constant `'\0'` where appropriate, instead of `1` and `0`.
- Provide one-line descriptive comments for each function.
- Do not use the `alloca()` function for allocating memory off the stack. Its use causes more portability trouble than is worth the minor benefit of not having to free the storage. Instead, use `malloc()` and `free()`.
- Do not use comparisons of the form '`! strcmp(a, b)`' or similar. As Henry Spencer once said, "`strcmp()` is not a boolean!" Instead, use '`strcmp(a, b) == 0`'.
- If adding new bit flag values, use explicit hexadecimal constants (`0x001`, `0x002`, `0x004`, and son on) instead of shifting one left by successive amounts ('`(1<<0)`', '`(1<<1)`', and so on).

  NOTE: If I have to reformat your code to follow the coding style used in `gawk`, I may not bother to integrate your changes at all.

6. Update the documentation. Along with your new code, please supply new sections and/or chapters for this book. If at all possible, please use real Texinfo, instead of just supplying unformatted ASCII text (although even that is better than no documentation at all). Conventions to be followed in *GAWK: Effective AWK Programming* are provided after the '`@bye`' at the end of the Texinfo source file. If possible, please update the `man` page as well.

   You will also have to sign paperwork for your documentation changes.

7. Submit changes as unified diffs. Use '`diff -u -r -N`' to compare the original `gawk` source tree with your version. I recommend using the GNU version of `diff`, or best of all, '`git diff`' or '`git format-patch`'. Send the output produced by `diff` to me when you submit your changes. (See Section B.4 [Reporting Problems and Bugs], page 410, for the electronic mail information.)

   Using this format makes it easy for me to apply your changes to the master version of the `gawk` source code (using `patch`). If I have to apply the changes manually, using a text editor, I may not do so, particularly if there are lots of changes.

8. Include an entry for the `ChangeLog` file with your submission. This helps further minimize the amount of work I have to do, making it easier for me to accept patches.

Although this sounds like a lot of work, please remember that while you may write the new code, I have to maintain it and support it. If it isn't possible for me to do that with a minimum of extra work, then I probably will not.

C.2.3 Porting `gawk` to a New Operating System

If you want to port `gawk` to a new operating system, there are several steps:

1. Follow the guidelines in the previous section concerning coding style, submission of diffs, and so on.
2. Be prepared to sign the appropriate paperwork. In order for the FSF to distribute your code, you must either place your code in the public domain and submit a signed statement to that effect, or assign the copyright in your code to the FSF.
3. When doing a port, bear in mind that your code must coexist peacefully with the rest of `gawk` and the other ports. Avoid gratuitous changes to the system-independent parts

of the code. If at all possible, avoid sprinkling '#ifdef's just for your port throughout the code.

If the changes needed for a particular system affect too much of the code, I probably will not accept them. In such a case, you can, of course, distribute your changes on your own, as long as you comply with the GPL (see [GNU General Public License], page 439).

4. A number of the files that come with gawk are maintained by other people. Thus, you should not change them unless it is for a very good reason; i.e., changes are not out of the question, but changes to these files are scrutinized extra carefully. The files are dfa.c, dfa.h, getopt1.c, getopt.c, getopt.h, install-sh, mkinstalldirs, regcomp.c, regex.c, regexec.c, regexex.c, regex.h, regex_internal.c, and regex_internal.h.
5. Be willing to continue to maintain the port. Non-Unix operating systems are supported by volunteers who maintain the code needed to compile and run gawk on their systems. If noone volunteers to maintain a port, it becomes unsupported and it may be necessary to remove it from the distribution.
6. Supply an appropriate gawkmisc.??? file. Each port has its own gawkmisc.??? that implements certain operating system specific functions. This is cleaner than a plethora of '#ifdef's scattered throughout the code. The gawkmisc.c in the main source directory includes the appropriate gawkmisc.??? file from each subdirectory. Be sure to update it as well.

   Each port's gawkmisc.??? file has a suffix reminiscent of the machine or operating system for the port—for example, pc/gawkmisc.pc and vms/gawkmisc.vms. The use of separate suffixes, instead of plain gawkmisc.c, makes it possible to move files from a port's subdirectory into the main subdirectory, without accidentally destroying the real gawkmisc.c file. (Currently, this is only an issue for the PC operating system ports.)
7. Supply a Makefile as well as any other C source and header files that are necessary for your operating system. All your code should be in a separate subdirectory, with a name that is the same as, or reminiscent of, either your operating system or the computer system. If possible, try to structure things so that it is not necessary to move files out of the subdirectory into the main source directory. If that is not possible, then be sure to avoid using names for your files that duplicate the names of files in the main source directory.
8. Update the documentation. Please write a section (or sections) for this book describing the installation and compilation steps needed to compile and/or install gawk for your system.

Following these steps makes it much easier to integrate your changes into gawk and have them coexist happily with other operating systems' code that is already there.

In the code that you supply and maintain, feel free to use a coding style and brace layout that suits your taste.

C.2.4 Why Generated Files Are Kept In git

If you look at the gawk source in the git repository, you will notice that it includes files that are automatically generated by GNU infrastructure tools, such as Makefile.in from automake and even configure from autoconf.

This is different from many Free Software projects that do not store the derived files, because that keeps the repository less cluttered, and it is easier to see the substantive changes when comparing versions and trying to understand what changed between commits.

However, there are two reasons why the gawk maintainer likes to have everything in the repository.

First, because it is then easy to reproduce any given version completely, without relying upon the availability of (older, likely obsolete, and maybe even impossible to find) other tools.

As an extreme example, if you ever even think about trying to compile, oh, say, the V7 awk, you will discover that not only do you have to bootstrap the V7 yacc to do so, but you also need the V7 lex. And the latter is pretty much impossible to bring up on a modern GNU/Linux system.[1]

(Or, let's say gawk 1.2 required bison whatever-it-was in 1989 and that there was no awkgram.c file in the repository. Is there a guarantee that we could find that bison version? Or that *it* would build?)

If the repository has all the generated files, then it's easy to just check them out and build. (Or *easier*, depending upon how far back we go. :-))

And that brings us to the second (and stronger) reason why all the files really need to be in git. It boils down to who do you cater to—the gawk developer(s), or the user who just wants to check out a version and try it out?

The gawk maintainer wants it to be possible for any interested awk user in the world to just clone the repository, check out the branch of interest and build it. Without their having to have the correct version(s) of the autotools.[2] That is the point of the bootstrap.sh file. It touches the various other files in the right order such that

```
# The canonical incantation for building GNU software:
./bootstrap.sh && ./configure && make
```

will *just work*.

This is extremely important for the master and gawk-*X.Y*-stable branches.

Further, the gawk maintainer would argue that it's also important for the gawk developers. When he tried to check out the xgawk branch[3] to build it, he couldn't. (No ltmain.sh file, and he had no idea how to create it, and that was not the only problem.)

---

[1] We tried. It was painful.

[2] There is one GNU program that is (in our opinion) severely difficult to bootstrap from the git repository. For example, on the author's old (but still working) PowerPC macintosh with Mac OS X 10.5, it was necessary to bootstrap a ton of software, starting with git itself, in order to try to work with the latest code. It's not pleasant, and especially on older systems, it's a big waste of time.

Starting with the latest tarball was no picnic either. The maintainers had dropped .gz and .bz2 files and only distribute .tar.xz files. It was necessary to bootstrap xz first!

[3] A branch created by one of the other developers that did not include the generated files.

He felt *extremely* frustrated. With respect to that branch, the maintainer is no different than Jane User who wants to try to build `gawk-4.0-stable` or `master` from the repository.

Thus, the maintainer thinks that it's not just important, but critical, that for any given branch, the above incantation *just works*.

What are some of the consequences and/or actions to take?

1. We don't mind that there are differing files in the different branches as a result of different versions of the autotools.
   A. It's the maintainer's job to merge them and he will deal with it.
   B. He is really good at '`git diff x y > /tmp/diff1 ; gvim /tmp/diff1`' to remove the diffs that aren't of interest in order to review code. `:-)`
2. It would certainly help if everyone used the same versions of the GNU tools as he does, which in general are the latest released versions of `automake`, `autoconf`, `bison`, and `gettext`.
   A. Installing from source is quite easy. It's how the maintainer worked for years under Fedora. He had `/usr/local/bin` at the front of his `PATH` and just did:

      ```
      wget http://ftp.gnu.org/gnu/package/package-x.y.z.tar.gz
      tar -xpzvf package-x.y.z.tar.gz
      cd package-x.y.z
      ./configure && make && make check
      make install    # as root
      ```

   B. These days the maintainer uses Ubuntu 12.04 which is medium current, but he is already doing the above for `autoconf`, `automake` and `bison`.

Most of the above was originally written by the maintainer to other `gawk` developers. It raised the objection from one of the developers "... that anybody pulling down the source from `git` is not an end user."

However, this is not true. There are "power `awk` users" who can build `gawk` (using the magic incantation shown previously) but who can't program in C. Thus, the major branches should be kept buildable all the time.

It was then suggested that there be a `cron` job to create nightly tarballs of "the source." Here, the problem is that there are source trees, corresponding to the various branches! So, nightly tar balls aren't the answer, especially as the repository can go for weeks without significant change being introduced.

Fortunately, the `git` server can meet this need. For any given branch named *branchname*, use:

```
wget http://git.savannah.gnu.org/cgit/gawk.git/snapshot/gawk-branchname.tar.gz
```

to retrieve a snapshot of the given branch.

C.3 Probable Future Extensions

AWK is a language similar to PERL, only considerably more elegant.
Arnold Robbins

Hey!
Larry Wall

The TODO file in the gawk Git repository lists possible future enhancements. Some of these relate to the source code, and others to possible new features. Please see that file for the list. See Section C.2 [Making Additions to gawk], page 415, if you are interested in tackling any of the projects listed there.

C.4 Some Limitations of the Implementation

This following table describes limits of gawk on a Unix-like system (although it is variable even then). Other systems may have different limits.

Item	**Limit**
Characters in a character class	2^(number of bits per byte)
Length of input record	MAX_INT
Length of output record	Unlimited
Length of source line	Unlimited
Number of fields in a record	MAX_LONG
Number of file redirections	Unlimited
Number of input records in one file	MAX_LONG
Number of input records total	MAX_LONG
Number of pipe redirections	min(number of processes per user, number of open files)
Numeric values	Double-precision floating point (if not using MPFR)
Size of a field	MAX_INT
Size of a literal string	MAX_INT
Size of a printf string	MAX_INT

C.5 Extension API Design

This section documents the design of the extension API, including a discussion of some of the history and problems that needed to be solved.

The first version of extensions for gawk was developed in the mid-1990s and released with gawk 3.1 in the late 1990s. The basic mechanisms and design remained unchanged for close to 15 years, until 2012.

The old extension mechanism used data types and functions from gawk itself, with a "clever hack" to install extension functions.

gawk included some sample extensions, of which a few were really useful. However, it was clear from the outset that the extension mechanism was bolted onto the side and was not really well thought out.

C.5.1 Problems With The Old Mechanism

The old extension mechanism had several problems:

- It depended heavily upon gawk internals. Any time the NODE structure[4] changed, an extension would have to be recompiled. Furthermore, to really write extensions required understanding something about gawk's internal functions. There was some documentation in this book, but it was quite minimal.

[4] A critical central data structure inside gawk.

- Being able to call into gawk from an extension required linker facilities that are common on Unix-derived systems but that did not work on Windows systems; users wanting extensions on Windows had to statically link them into gawk, even though Windows supports dynamic loading of shared objects.
- The API would change occasionally as gawk changed; no compatibility between versions was ever offered or planned for.

Despite the drawbacks, the xgawk project developers forked gawk and developed several significant extensions. They also enhanced gawk's facilities relating to file inclusion and shared object access.

A new API was desired for a long time, but only in 2012 did the gawk maintainer and the xgawk developers finally start working on it together. More information about the xgawk project is provided in Section 16.8 [The gawkextlib Project], page 384.

C.5.2 Goals For A New Mechanism

Some goals for the new API were:

- The API should be independent of gawk internals. Changes in gawk internals should not be visible to the writer of an extension function.
- The API should provide *binary* compatibility across gawk releases as long as the API itself does not change.
- The API should enable extensions written in C or C++ to have roughly the same "appearance" to awk-level code as awk functions do. This means that extensions should have:
  - The ability to access function parameters.
  - The ability to turn an undefined parameter into an array (call by reference).
  - The ability to create, access and update global variables.
  - Easy access to all the elements of an array at once ("array flattening") in order to loop over all the element in an easy fashion for C code.
  - The ability to create arrays (including gawk's true multidimensional arrays).

Some additional important goals were:

- The API should use only features in ISO C 90, so that extensions can be written using the widest range of C and C++ compilers. The header should include the appropriate '#ifdef __cplusplus' and 'extern "C"' magic so that a C++ compiler could be used. (If using C++, the runtime system has to be smart enough to call any constructors and destructors, as gawk is a C program. As of this writing, this has not been tested.)
- The API mechanism should not require access to gawk's symbols[5] by the compile-time or dynamic linker, in order to enable creation of extensions that also work on Windows.

During development, it became clear that there were other features that should be available to extensions, which were also subsequently provided:

- Extensions should have the ability to hook into gawk's I/O redirection mechanism. In particular, the xgawk developers provided a so-called "open hook" to take over reading

[5] The *symbols* are the variables and functions defined inside gawk. Access to these symbols by code external to gawk loaded dynamically at runtime is problematic on Windows.

records. During development, this was generalized to allow extensions to hook into input processing, output processing, and two-way I/O.

- An extension should be able to provide a "call back" function to perform clean up actions when `gawk` exits.
- An extension should be able to provide a version string so that `gawk`'s `--version` option can provide information about extensions as well.

The requirement to avoid access to `gawk`'s symbols is, at first glance, a difficult one to meet.

One design, apparently used by Perl and Ruby and maybe others, would be to make the mainline `gawk` code into a library, with the `gawk` utility a small C `main()` function linked against the library.

This seemed like the tail wagging the dog, complicating build and installation and making a simple copy of the `gawk` executable from one system to another (or one place to another on the same system!) into a chancy operation.

Pat Rankin suggested the solution that was adopted. See Section 16.3 [At A High Level How It Works], page 333, for the details.

C.5.3 Other Design Decisions

As an arbitrary design decision, extensions can read the values of built-in variables and arrays (such as `ARGV` and `FS`), but cannot change them, with the exception of `PROCINFO`.

The reason for this is to prevent an extension function from affecting the flow of an `awk` program outside its control. While a real `awk` function can do what it likes, that is at the discretion of the programmer. An extension function should provide a service or make a C API available for use within `awk`, and not mess with `FS` or `ARGC` and `ARGV`.

In addition, it becomes easy to start down a slippery slope. How much access to `gawk` facilities do extensions need? Do they need `getline`? What about calling `gsub()` or compiling regular expressions? What about calling into `awk` functions? (*That* would be messy.)

In order to avoid these issues, the `gawk` developers chose to start with the simplest, most basic features that are still truly useful.

Another decision is that although `gawk` provides nice things like MPFR, and arrays indexed internally by integers, these features are not being brought out to the API in order to keep things simple and close to traditional `awk` semantics. (In fact, arrays indexed internally by integers are so transparent that they aren't even documented!)

Additionally, all functions in the API check that their pointer input parameters are not `NULL`. If they are, they return an error. (It is a good idea for extension code to verify that pointers received from `gawk` are not `NULL`. Such a thing should not happen, but the `gawk` developers are only human, and they have been known to occasionally make mistakes.)

With time, the API will undoubtedly evolve; the `gawk` developers expect this to be driven by user needs. For now, the current API seems to provide a minimal yet powerful set of features for creating extensions.

C.5.4 Room For Future Growth

The API can later be expanded, in two ways:

- gawk passes an "extension id" into the extension when it first loads the extension. The extension then passes this id back to gawk with each function call. This mechanism allows gawk to identify the extension calling into it, should it need to know.
- Similarly, the extension passes a "name space" into gawk when it registers each extension function. This accommodates a possible future mechanism for grouping extension functions and possibly avoiding name conflicts.

Of course, as of this writing, no decisions have been made with respect to any of the above.

C.6 Compatibility For Old Extensions

Chapter 16 [Writing Extensions for gawk], page 333, describes the supported API and mechanisms for writing extensions for gawk. This API was introduced in version 4.1. However, for many years gawk provided an extension mechanism that required knowledge of gawk internals and that was not as well designed.

In order to provide a transition period, gawk version 4.1 continues to support the original extension mechanism. This will be true for the life of exactly one major release. This support will be withdrawn, and removed from the source code, at the next major release.

Briefly, original-style extensions should be compiled by including the awk.h header file in the extension source code. Additionally, you must define the identifier 'GAWK' when building (use '-DGAWK' with Unix-style compilers). Otherwise, the definitions in gawkapi.h will cause conflicts with those in awk.h and your extension will not compile.

Just as in previous versions, you load an old-style extension with the extension() built-in function (which is not otherwise documented). This function in turn finds and loads the shared object file containing the extension and calls its dl_load() C routine.

Because original-style and new-style extensions use different initialization routines (dl_load() versus dlload()), they may safely be installed in the same directory (to be found by AWKLIBPATH) without conflict.

The gawk development team strongly recommends that you convert any old extensions that you may have to use the new API described in Chapter 16 [Writing Extensions for gawk], page 333.

Appendix D Basic Programming Concepts

This appendix attempts to define some of the basic concepts and terms that are used throughout the rest of this book. As this book is specifically about `awk`, and not about computer programming in general, the coverage here is by necessity fairly cursory and simplistic. (If you need more background, there are many other introductory texts that you should refer to instead.)

D.1 What a Program Does

At the most basic level, the job of a program is to process some input data and produce results. See Figure D.1.

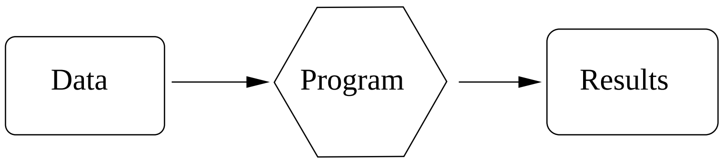

Figure D.1: General Program Flow

The "program" in the figure can be either a compiled program[1] (such as `ls`), or it may be *interpreted*. In the latter case, a machine-executable program such as `awk` reads your program, and then uses the instructions in your program to process the data.

When you write a program, it usually consists of the following, very basic set of steps, as shown in Figure D.2:

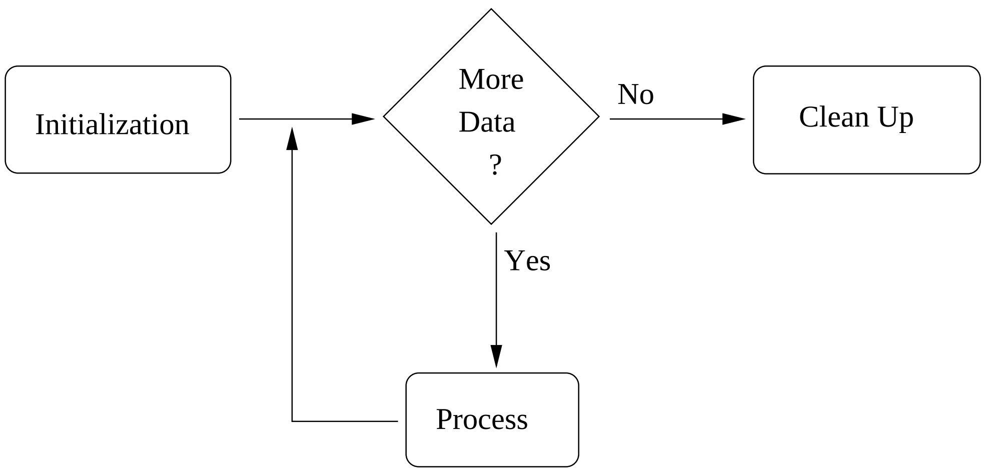

Figure D.2: Basic Program Steps

[1] Compiled programs are typically written in lower-level languages such as C, C++, or Ada, and then translated, or *compiled*, into a form that the computer can execute directly.

Initialization
: These are the things you do before actually starting to process data, such as checking arguments, initializing any data you need to work with, and so on. This step corresponds to `awk`'s `BEGIN` rule (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122).

  If you were baking a cake, this might consist of laying out all the mixing bowls and the baking pan, and making sure you have all the ingredients that you need.

Processing
: This is where the actual work is done. Your program reads data, one logical chunk at a time, and processes it as appropriate.

  In most programming languages, you have to manually manage the reading of data, checking to see if there is more each time you read a chunk. `awk`'s pattern-action paradigm (see Chapter 1 [Getting Started with `awk`], page 15) handles the mechanics of this for you.

  In baking a cake, the processing corresponds to the actual labor: breaking eggs, mixing the flour, water, and other ingredients, and then putting the cake into the oven.

Clean Up
: Once you've processed all the data, you may have things you need to do before exiting. This step corresponds to `awk`'s `END` rule (see Section 7.1.4 [The `BEGIN` and `END` Special Patterns], page 122).

  After the cake comes out of the oven, you still have to wrap it in plastic wrap to keep anyone from tasting it, as well as wash the mixing bowls and utensils.

An *algorithm* is a detailed set of instructions necessary to accomplish a task, or process data. It is much the same as a recipe for baking a cake. Programs implement algorithms. Often, it is up to you to design the algorithm and implement it, simultaneously.

The "logical chunks" we talked about previously are called *records*, similar to the records a company keeps on employees, a school keeps for students, or a doctor keeps for patients. Each record has many component parts, such as first and last names, date of birth, address, and so on. The component parts are referred to as the *fields* of the record.

The act of reading data is termed *input*, and that of generating results, not too surprisingly, is termed *output*. They are often referred to together as "input/output," and even more often, as "I/O" for short. (You will also see "input" and "output" used as verbs.)

`awk` manages the reading of data for you, as well as the breaking it up into records and fields. Your program's job is to tell `awk` what to do with the data. You do this by describing *patterns* in the data to look for, and *actions* to execute when those patterns are seen. This *data-driven* nature of `awk` programs usually makes them both easier to write and easier to read.

D.2 Data Values in a Computer

In a program, you keep track of information and values in things called *variables*. A variable is just a name for a given value, such as `first_name`, `last_name`, `address`, and so on. `awk` has several predefined variables, and it has special names to refer to the current input record and the fields of the record. You may also group multiple associated values under one name, as an array.

Data, particularly in `awk`, consists of either numeric values, such as 42 or 3.1415927, or string values. String values are essentially anything that's not a number, such as a name. Strings are sometimes referred to as *character data*, since they store the individual characters that comprise them. Individual variables, as well as numeric and string variables, are referred to as *scalar* values. Groups of values, such as arrays, are not scalars.

Section 15.1 [A General Description of Computer Arithmetic], page 317, provided a basic introduction to numeric types (integer and floating-point) and how they are used in a computer. Please review that information, including a number of caveats that were presented.

While you are probably used to the idea of a number without a value (i.e., zero), it takes a bit more getting used to the idea of zero-length character data. Nevertheless, such a thing exists. It is called the *null string*. The null string is character data that has no value. In other words, it is empty. It is written in `awk` programs like this: `""`.

Humans are used to working in decimal; i.e., base 10. In base 10, numbers go from 0 to 9, and then "roll over" into the next column. (Remember grade school? 42 is 4 times 10 plus 2.)

There are other number bases though. Computers commonly use base 2 or *binary*, base 8 or *octal*, and base 16 or *hexadecimal*. In binary, each column represents two times the value in the column to its right. Each column may contain either a 0 or a 1. Thus, binary 1010 represents 1 times 8, plus 0 times 4, plus 1 times 2, plus 0 times 1, or decimal 10. Octal and hexadecimal are discussed more in Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97.

At the very lowest level, computers store values as groups of binary digits, or *bits*. Modern computers group bits into groups of eight, called *bytes*. Advanced applications sometimes have to manipulate bits directly, and `gawk` provides functions for doing so.

Programs are written in programming languages. Hundreds, if not thousands, of programming languages exist. One of the most popular is the C programming language. The C language had a very strong influence on the design of the `awk` language.

There have been several versions of C. The first is often referred to as "K&R" C, after the initials of Brian Kernighan and Dennis Ritchie, the authors of the first book on C. (Dennis Ritchie created the language, and Brian Kernighan was one of the creators of `awk`.)

In the mid-1980s, an effort began to produce an international standard for C. This work culminated in 1989, with the production of the ANSI standard for C. This standard became an ISO standard in 1990. In 1999, a revised ISO C standard was approved and released. Where it makes sense, POSIX `awk` is compatible with 1999 ISO C.

Glossary

Action
: A series of `awk` statements attached to a rule. If the rule's pattern matches an input record, `awk` executes the rule's action. Actions are always enclosed in curly braces. (See Section 7.3 [Actions], page 125.)

Amazing `awk` Assembler
: Henry Spencer at the University of Toronto wrote a retargetable assembler completely as `sed` and `awk` scripts. It is thousands of lines long, including machine descriptions for several eight-bit microcomputers. It is a good example of a program that would have been better written in another language. You can get it from `http://awk.info/?awk100/aaa`.

Ada
: A programming language originally defined by the U.S. Department of Defense for embedded programming. It was designed to enforce good Software Engineering practices.

Amazingly Workable Formatter (`awf`)
: Henry Spencer at the University of Toronto wrote a formatter that accepts a large subset of the '`nroff -ms`' and '`nroff -man`' formatting commands, using `awk` and `sh`. It is available from `http://awk.info/?tools/awf`.

Anchor
: The regexp metacharacters '`^`' and '`$`', which force the match to the beginning or end of the string, respectively.

ANSI
: The American National Standards Institute. This organization produces many standards, among them the standards for the C and C++ programming languages. These standards often become international standards as well. See also "ISO."

Array
: A grouping of multiple values under the same name. Most languages just provide sequential arrays. `awk` provides associative arrays.

Assertion
: A statement in a program that a condition is true at this point in the program. Useful for reasoning about how a program is supposed to behave.

Assignment
: An `awk` expression that changes the value of some `awk` variable or data object. An object that you can assign to is called an *lvalue*. The assigned values are called *rvalues*. See Section 6.2.3 [Assignment Expressions], page 106.

Associative Array
: Arrays in which the indices may be numbers or strings, not just sequential integers in a fixed range.

`awk` Language
: The language in which `awk` programs are written.

`awk` Program
: An `awk` program consists of a series of *patterns* and *actions*, collectively known as *rules*. For each input record given to the program, the program's rules are all processed in turn. `awk` programs may also contain function definitions.

`awk` Script
: Another name for an `awk` program.

Bash
: The GNU version of the standard shell (the **B**ourne-**A**gain **SH**ell). See also "Bourne Shell."

BBS
: See "Bulletin Board System."

Bit
: Short for "Binary Digit." All values in computer memory ultimately reduce to binary digits: values that are either zero or one. Groups of bits may be interpreted differently—as integers, floating-point numbers, character data, addresses of other memory objects, or other data. `awk` lets you work with floating-point numbers and strings. `gawk` lets you manipulate bit values with the built-in functions described in Section 9.1.6 [Bit-Manipulation Functions], page 181.

  Computers are often defined by how many bits they use to represent integer values. Typical systems are 32-bit systems, but 64-bit systems are becoming increasingly popular, and 16-bit systems have essentially disappeared.

Boolean Expression
: Named after the English mathematician Boole. See also "Logical Expression."

Bourne Shell
: The standard shell (`/bin/sh`) on Unix and Unix-like systems, originally written by Steven R. Bourne. Many shells (Bash, `ksh`, `pdksh`, `zsh`) are generally upwardly compatible with the Bourne shell.

Built-in Function
: The `awk` language provides built-in functions that perform various numerical, I/O-related, and string computations. Examples are `sqrt()` (for the square root of a number) and `substr()` (for a substring of a string). `gawk` provides functions for timestamp management, bit manipulation, array sorting, type checking, and runtime string translation. (See Section 9.1 [Built-in Functions], page 159.)

Built-in Variable
: `ARGC`, `ARGV`, `CONVFMT`, `ENVIRON`, `FILENAME`, `FNR`, `FS`, `NF`, `NR`, `OFMT`, `OFS`, `ORS`, `RLENGTH`, `RSTART`, `RS`, and `SUBSEP` are the variables that have special meaning to `awk`. In addition, `ARGIND`, `BINMODE`, `ERRNO`, `FIELDWIDTHS`, `FPAT`, `IGNORECASE`, `LINT`, `PROCINFO`, `RT`, and `TEXTDOMAIN` are the variables that have special meaning to `gawk`. Changing some of them affects `awk`'s running environment. (See Section 7.5 [Built-in Variables], page 134.)

Braces
: See "Curly Braces."

Bulletin Board System
: A computer system allowing users to log in and read and/or leave messages for other users of the system, much like leaving paper notes on a bulletin board.

C
: The system programming language that most GNU software is written in. The `awk` programming language has C-like syntax, and this book points out similarities between `awk` and C when appropriate.

  In general, `gawk` attempts to be as similar to the 1990 version of ISO C as makes sense.

C++
: A popular object-oriented programming language derived from C.

Character Set
: The set of numeric codes used by a computer system to represent the characters (letters, numbers, punctuation, etc.) of a particular country or place. The most common character set in use today is ASCII (American Standard Code for Information Interchange). Many European countries use an extension of ASCII known as ISO-8859-1 (ISO Latin-1). The Unicode character set (`http://www.unicode.org`) is becoming increasingly popular and standard, and is particularly widely used on GNU/Linux systems.

CHEM
: A preprocessor for `pic` that reads descriptions of molecules and produces `pic` input for drawing them. It was written in `awk` by Brian Kernighan and Jon Bentley, and is available from `http://netlib.sandia.gov/netlib/typesetting/chem.gz`.

Cookie
: A peculiar goodie, token, saying or remembrance produced by or presented to a program. (With thanks to Doug McIlroy.)

Coprocess
: A subordinate program with which two-way communications is possible.

Compiler
: A program that translates human-readable source code into machine-executable object code. The object code is then executed directly by the computer. See also "Interpreter."

Compound Statement
: A series of `awk` statements, enclosed in curly braces. Compound statements may be nested. (See Section 7.4 [Control Statements in Actions], page 126.)

Concatenation
: Concatenating two strings means sticking them together, one after another, producing a new string. For example, the string '`foo`' concatenated with the string '`bar`' gives the string '`foobar`'. (See Section 6.2.2 [String Concatenation], page 104.)

Conditional Expression
: An expression using the '`?:`' ternary operator, such as '`expr1 ? expr2 : expr3`'. The expression *expr1* is evaluated; if the result is true, the value of the whole expression is the value of *expr2*; otherwise the value is *expr3*. In either case, only one of *expr2* and *expr3* is evaluated. (See Section 6.3.4 [Conditional Expressions], page 115.)

Comparison Expression
: A relation that is either true or false, such as '`a < b`'. Comparison expressions are used in `if`, `while`, `do`, and `for` statements, and in patterns to select which input records to process. (See Section 6.3.2 [Variable Typing and Comparison Expressions], page 110.)

Curly Braces
: The characters '`{`' and '`}`'. Curly braces are used in `awk` for delimiting actions, compound statements, and function bodies.

Dark Corner
: An area in the language where specifications often were (or still are) not clear, leading to unexpected or undesirable behavior. Such areas are marked in this

book with the picture of a flashlight in the margin and are indexed under the heading "dark corner."

Data Driven
: A description of `awk` programs, where you specify the data you are interested in processing, and what to do when that data is seen.

Data Objects
: These are numbers and strings of characters. Numbers are converted into strings and vice versa, as needed. (See Section 6.1.4 [Conversion of Strings and Numbers], page 101.)

Deadlock
: The situation in which two communicating processes are each waiting for the other to perform an action.

Debugger
: A program used to help developers remove "bugs" from (de-bug) their programs.

Double Precision
: An internal representation of numbers that can have fractional parts. Double precision numbers keep track of more digits than do single precision numbers, but operations on them are sometimes more expensive. This is the way `awk` stores numeric values. It is the C type `double`.

Dynamic Regular Expression
: A dynamic regular expression is a regular expression written as an ordinary expression. It could be a string constant, such as `"foo"`, but it may also be an expression whose value can vary. (See Section 3.8 [Using Dynamic Regexps], page 53.)

Environment
: A collection of strings, of the form *name*`=`*val*, that each program has available to it. Users generally place values into the environment in order to provide information to various programs. Typical examples are the environment variables `HOME` and `PATH`.

Empty String
: See "Null String."

Epoch
: The date used as the "beginning of time" for timestamps. Time values in most systems are represented as seconds since the epoch, with library functions available for converting these values into standard date and time formats.

: The epoch on Unix and POSIX systems is 1970-01-01 00:00:00 UTC. See also "GMT" and "UTC."

Escape Sequences
: A special sequence of characters used for describing nonprinting characters, such as '`\n`' for newline or '`\033`' for the ASCII ESC (Escape) character. (See Section 3.2 [Escape Sequences], page 44.)

Extension
: An additional feature or change to a programming language or utility not defined by that language's or utility's standard. `gawk` has (too) many extensions over POSIX `awk`.

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Field When awk reads an input record, it splits the record into pieces separated by whitespace (or by a separator regexp that you can change by setting the built-in variable FS). Such pieces are called fields. If the pieces are of fixed length, you can use the built-in variable FIELDWIDTHS to describe their lengths. If you wish to specify the contents of fields instead of the field separator, you can use the built-in variable FPAT to do so. (See Section 4.5 [Specifying How Fields Are Separated], page 62, Section 4.6 [Reading Fixed-Width Data], page 67, and Section 4.7 [Defining Fields By Content], page 69.)

Flag A variable whose truth value indicates the existence or nonexistence of some condition.

Floating-Point Number
Often referred to in mathematical terms as a "rational" or real number, this is just a number that can have a fractional part. See also "Double Precision" and "Single Precision."

Format Format strings are used to control the appearance of output in the strftime() and sprintf() functions, and are used in the printf statement as well. Also, data conversions from numbers to strings are controlled by the format strings contained in the built-in variables CONVFMT and OFMT. (See Section 5.5.2 [Format-Control Letters], page 84.)

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Function A specialized group of statements used to encapsulate general or program-specific tasks. awk has a number of built-in functions, and also allows you to define your own. (See Chapter 9 [Functions], page 159.)

FSF See "Free Software Foundation."

Free Software Foundation
A nonprofit organization dedicated to the production and distribution of freely distributable software. It was founded by Richard M. Stallman, the author of the original Emacs editor. GNU Emacs is the most widely used version of Emacs today.

gawk The GNU implementation of awk.

General Public License
This document describes the terms under which gawk and its source code may be distributed. (See [GNU General Public License], page 439.)

GMT "Greenwich Mean Time." This is the old term for UTC. It is the time of day used internally for Unix and POSIX systems. See also "Epoch" and "UTC."

GNU "GNU's not Unix". An on-going project of the Free Software Foundation to create a complete, freely distributable, POSIX-compliant computing environment.

GNU/Linux
: A variant of the GNU system using the Linux kernel, instead of the Free Software Foundation's Hurd kernel. The Linux kernel is a stable, efficient, full-featured clone of Unix that has been ported to a variety of architectures. It is most popular on PC-class systems, but runs well on a variety of other systems too. The Linux kernel source code is available under the terms of the GNU General Public License, which is perhaps its most important aspect.

GPL
: See "General Public License."

Hexadecimal
: Base 16 notation, where the digits are `0`–`9` and `A`–`F`, with '`A`' representing 10, '`B`' representing 11, and so on, up to '`F`' for 15. Hexadecimal numbers are written in C using a leading '`0x`', to indicate their base. Thus, `0x12` is 18 (1 times 16 plus 2). See Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97.

I/O
: Abbreviation for "Input/Output," the act of moving data into and/or out of a running program.

Input Record
: A single chunk of data that is read in by `awk`. Usually, an `awk` input record consists of one line of text. (See Section 4.1 [How Input Is Split into Records], page 55.)

Integer
: A whole number, i.e., a number that does not have a fractional part.

Internationalization
: The process of writing or modifying a program so that it can use multiple languages without requiring further source code changes.

Interpreter
: A program that reads human-readable source code directly, and uses the instructions in it to process data and produce results. `awk` is typically (but not always) implemented as an interpreter. See also "Compiler."

Interval Expression
: A component of a regular expression that lets you specify repeated matches of some part of the regexp. Interval expressions were not originally available in `awk` programs.

ISO
: The International Organization for Standardization. This organization produces international standards for many things, including programming languages, such as C and C++. In the computer arena, important standards like those for C, C++, and POSIX become both American national and ISO international standards simultaneously. This book refers to Standard C as "ISO C" throughout. See the ISO website (`http://www.iso.org/iso/home/about.htm`) for more information about the name of the organization and its language-independent three-letter acronym.

Java
: A modern programming language originally developed by Sun Microsystems (now Oracle) supporting Object-Oriented programming. Although usually implemented by compiling to the instructions for a standard virtual machine (the JVM), the language can be compiled to native code.

Keyword — In the awk language, a keyword is a word that has special meaning. Keywords are reserved and may not be used as variable names.

gawk's keywords are: BEGIN, BEGINFILE, END, ENDFILE, break, case, continue, default delete, do...while, else, exit, for...in, for, function, func, if, nextfile, next, switch, and while.

Lesser General Public License
: This document describes the terms under which binary library archives or shared objects, and their source code may be distributed.

Linux — See "GNU/Linux."

LGPL — See "Lesser General Public License."

Localization
: The process of providing the data necessary for an internationalized program to work in a particular language.

Logical Expression
: An expression using the operators for logic, AND, OR, and NOT, written '&&', '||', and '!' in awk. Often called Boolean expressions, after the mathematician who pioneered this kind of mathematical logic.

Lvalue — An expression that can appear on the left side of an assignment operator. In most languages, lvalues can be variables or array elements. In awk, a field designator can also be used as an lvalue.

Matching — The act of testing a string against a regular expression. If the regexp describes the contents of the string, it is said to *match* it.

Metacharacters
: Characters used within a regexp that do not stand for themselves. Instead, they denote regular expression operations, such as repetition, grouping, or alternation.

No-op — An operation that does nothing.

Null String
: A string with no characters in it. It is represented explicitly in awk programs by placing two double quote characters next to each other (""). It can appear in input data by having two successive occurrences of the field separator appear next to each other.

Number — A numeric-valued data object. Modern awk implementations use double precision floating-point to represent numbers. Ancient awk implementations used single precision floating-point.

Octal — Base-eight notation, where the digits are 0–7. Octal numbers are written in C using a leading '0', to indicate their base. Thus, 013 is 11 (one times 8 plus 3). See Section 6.1.1.2 [Octal and Hexadecimal Numbers], page 97.

P1003.1 — See "POSIX."

Pattern — Patterns tell awk which input records are interesting to which rules.

A pattern is an arbitrary conditional expression against which input is tested. If the condition is satisfied, the pattern is said to *match* the input record. A typical pattern might compare the input record against a regular expression. (See Section 7.1 [Pattern Elements], page 119.)

PEBKAC
: An acronym describing what is possibly the most frequent source of computer usage problems. (Problem Exists Between Keyboard And Chair.)

POSIX
: The name for a series of standards that specify a Portable Operating System interface. The "IX" denotes the Unix heritage of these standards. The main standard of interest for `awk` users is *IEEE Standard for Information Technology, Standard 1003.1-2008*. The 2008 POSIX standard can be found online at `http://www.opengroup.org/onlinepubs/9699919799/`.

Precedence
: The order in which operations are performed when operators are used without explicit parentheses.

Private
: Variables and/or functions that are meant for use exclusively by library functions and not for the main `awk` program. Special care must be taken when naming such variables and functions. (See Section 10.1 [Naming Library Function Global Variables], page 202.)

Range (of input lines)
: A sequence of consecutive lines from the input file(s). A pattern can specify ranges of input lines for `awk` to process or it can specify single lines. (See Section 7.1 [Pattern Elements], page 119.)

Recursion
: When a function calls itself, either directly or indirectly. As long as this is not clear, refer to the entry for "recursion." If this is clear, stop, and proceed to the next entry.

Redirection
: Redirection means performing input from something other than the standard input stream, or performing output to something other than the standard output stream.

You can redirect input to the `getline` statement using the '`<`', '`|`', and '`|&`' operators. You can redirect the output of the `print` and `printf` statements to a file or a system command, using the '`>`', '`>>`', '`|`', and '`|&`' operators. (See Section 4.9 [Explicit Input with `getline`], page 73, and Section 5.6 [Redirecting Output of `print` and `printf`], page 89.)

Regexp
: See "Regular Expression."

Regular Expression
: A regular expression ("regexp" for short) is a pattern that denotes a set of strings, possibly an infinite set. For example, the regular expression '`R.*xp`' matches any string starting with the letter '`R`' and ending with the letters '`xp`'. In `awk`, regular expressions are used in patterns and in conditional expressions. Regular expressions may contain escape sequences. (See Chapter 3 [Regular Expressions], page 43.)

Regular Expression Constant
: A regular expression constant is a regular expression written within slashes, such as `/foo/`. This regular expression is chosen when you write the `awk` program and cannot be changed during its execution. (See Section 3.1 [How to Use Regular Expressions], page 43.)

Rule
: A segment of an `awk` program that specifies how to process single input records. A rule consists of a *pattern* and an *action*. `awk` reads an input record; then, for each rule, if the input record satisfies the rule's pattern, `awk` executes the rule's action. Otherwise, the rule does nothing for that input record.

Rvalue
: A value that can appear on the right side of an assignment operator. In `awk`, essentially every expression has a value. These values are rvalues.

Scalar
: A single value, be it a number or a string. Regular variables are scalars; arrays and functions are not.

Search Path
: In `gawk`, a list of directories to search for `awk` program source files. In the shell, a list of directories to search for executable programs.

Seed
: The initial value, or starting point, for a sequence of random numbers.

`sed`
: See "Stream Editor."

Shell
: The command interpreter for Unix and POSIX-compliant systems. The shell works both interactively, and as a programming language for batch files, or shell scripts.

Short-Circuit
: The nature of the `awk` logical operators '`&&`' and '`||`'. If the value of the entire expression is determinable from evaluating just the lefthand side of these operators, the righthand side is not evaluated. (See Section 6.3.3 [Boolean Expressions], page 113.)

Side Effect
: A side effect occurs when an expression has an effect aside from merely producing a value. Assignment expressions, increment and decrement expressions, and function calls have side effects. (See Section 6.2.3 [Assignment Expressions], page 106.)

Single Precision
: An internal representation of numbers that can have fractional parts. Single precision numbers keep track of fewer digits than do double precision numbers, but operations on them are sometimes less expensive in terms of CPU time. This is the type used by some very old versions of `awk` to store numeric values. It is the C type `float`.

Space
: The character generated by hitting the space bar on the keyboard.

Special File
: A file name interpreted internally by `gawk`, instead of being handed directly to the underlying operating system—for example, `/dev/stderr`. (See Section 5.7 [Special File Names in `gawk`], page 92.)

Stream Editor
: A program that reads records from an input stream and processes them one or more at a time. This is in contrast with batch programs, which may expect to read their input files in entirety before starting to do anything, as well as with interactive programs which require input from the user.

String
: A datum consisting of a sequence of characters, such as '`I am a string`'. Constant strings are written with double quotes in the `awk` language and may contain escape sequences. (See Section 3.2 [Escape Sequences], page 44.)

Tab
: The character generated by hitting the *TAB* key on the keyboard. It usually expands to up to eight spaces upon output.

Text Domain
: A unique name that identifies an application. Used for grouping messages that are translated at runtime into the local language.

Timestamp
: A value in the "seconds since the epoch" format used by Unix and POSIX systems. Used for the `gawk` functions `mktime()`, `strftime()`, and `systime()`. See also "Epoch" and "UTC."

Unix
: A computer operating system originally developed in the early 1970's at AT&T Bell Laboratories. It initially became popular in universities around the world and later moved into commercial environments as a software development system and network server system. There are many commercial versions of Unix, as well as several work-alike systems whose source code is freely available (such as GNU/Linux, NetBSD (`http://www.netbsd.org`), FreeBSD (`http://www.freebsd.org`), and OpenBSD (`http://www.openbsd.org`)).

UTC
: The accepted abbreviation for "Universal Coordinated Time." This is standard time in Greenwich, England, which is used as a reference time for day and date calculations. See also "Epoch" and "GMT."

Whitespace
: A sequence of space, TAB, or newline characters occurring inside an input record or a string.

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