



Advanced Programming in the UNIX Environment (2nd Edition)

By W. Richard Stevens, Stephen A. Rago

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"Stephen Rago's update is a long overdue benefit to the community of professionals using the versatile family of UNIX and UNIX-like operating environments. It removes obsolescence and includes newer developments. It also thoroughly updates the context of all topics, examples, and applications to recent releases of popular implementations of UNIX and UNIX-like environments. And yet, it does all this while retaining the style and taste of the original classic."

--Mukesh Kacker, cofounder and former CTO of Pronto Networks, Inc.

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--Andrew Josey, Director, Certification, The Open Group, and Chair of the POSIX 1003.1 Working Group

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--Dr. Benjamin Kuperman, Swarthmore College

Praise for the First Edition

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--*UniForum Monthly*

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Rago carefully retains the spirit and approach that made this book a classic. Building on Stevens' work, he begins with basic topics such as files, directories, and processes, carefully laying the groundwork for understanding more advanced techniques, such as signal handling and terminal I/O.

Substantial new material includes chapters on threads and multithreaded programming, using the socket interface to drive interprocess communication (IPC), and extensive coverage of the interfaces added to the latest version of the POSIX.1 standard. Nearly all examples have been tested on four of today's most widely used UNIX/Linux platforms: FreeBSD 5.2.1; the Linux 2.4.22 kernel; Solaris 9; and Darwin 7.4.0, the FreeBSD/Mach hybrid underlying Apple's Mac OS X 10.3.

As in the first edition, you'll learn through example, including more than 10,000 lines of downloadable, ANSI C source code. More than 400 system calls and

functions are demonstrated with concise, complete programs that clearly illustrate their usage, arguments, and return values. To tie together what you've learned, the book presents several chapter-length case studies, each fully updated for contemporary environments.

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Editorial Review

From the Back Cover

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About the Author

We are deeply saddened to learn of the death of noted author **W. Richard Stevens**. His passing is obviously a tremendous loss for the technical community, but it is a personal one for us as well. Rich was both a gifted colleague and a valued friend who will be greatly missed. We extend our sympathies to his family.

Obituary from the *Arizona Daily Star*:

STEVENS, W. Richard, noted author of computer books died on September 1. He is best known for his "UNIX Network Programming" series (1990, 1998, 1999), "Advanced Programming in the UNIX Environment" (1992), and "TCP/IP Illustrated" series (1994, 1995, 1996). Richard was born in 1951 in Luanshya, Northern Rhodesia (now Zambia), where his father worked for the copper industry. The family moved to Salt Lake City, Hurley, New Mexico, Washington, DC and Phalaborwa, South Africa. Richard attended Fishburne Military School in Waynesboro, Virginia. He received a B.S.C. in Aerospace Engineering from the

University of Michigan in 1973, and an M.S. (1978) and Ph.D. (1982) in Systems Engineering from the University of Arizona. He moved to Tucson in 1975 and from then until 1982 he was employed at Kitt Peak National Observatory as a computer programmer. From 1982 until 1990 he was Vice President of Computing Services at Health Systems International in New Haven, CT, moving back to Tucson in 1990. Here he pursued his career as an author and consultant. He was also an avid pilot and a part-time flight instructor during the 1970's.

He is survived by his loving wife of 20 years, Sally Hodges Stevens; three wonderful children, Bill, Ellen and David; sister, Claire Stevens of Las Vegas, NV; brother, Bob and wife Linda Stevens of Dallas, TX; nieces, Laura, Sarah, Collette, Christy; and nephew, Brad. He is predeceased by his parents, Royale J. Stevens (1915-1984); and Helen Patterson Stevens (1916-1997). Helen lived in Tucson from 1991-1997, and Royale lived here in the early 1930's attending Tucson High School while his father was treated for TB at the Desert Sanatorium (now TMC). The family asks that in lieu of flowers, donations be made in Richard's name to Habitat for Humanity, 2950 E. 22nd Street, Tucson, AZ 85713. A memorial service for Richard will be held at St. Phillip's in the Hills Episcopal Church on Tuesday, September 7th at 12:00 noon. Following the service there will be a reception in the Murphy Gallery of the Church. Please wear colorful clothing to the service; Richard loved colors.

W. Richard Stevens was an acknowledged UNIX and networking expert and the highly-respected author of several books. He was also a sought-after instructor and consultant.

Stephen A. Rago, one of the Bell Laboratories developers who built UNIX System V, Release 4, currently works as a manager at EMC, specializing in file servers and file systems.

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Introduction

Rich Stevens and I first met through an e-mail exchange when I reported a typographical error in his first book, *UNIX Network Programming*. He used to kid me about being the person to send him his first errata notice for the book. Until his death in 1999, we exchanged e-mail irregularly, usually when one of us had a question we thought the other might be able to answer. We met for dinner at USENIX conferences and when Rich was teaching in the area.

Rich Stevens was a friend who always conducted himself as a gentleman. When I wrote *UNIX System V Network Programming* in 1993, I intended it to be a System V version of Rich's *UNIX Network Programming*. As was his nature, Rich gladly reviewed chapters for me, and treated me not as a competitor, but as a colleague. We often talked about collaborating on a STREAMS version of his *TCP/IP Illustrated* book. Had events been different, we might have actually done it, but since Rich is no longer with us, revising *Advanced Programming in the UNIX Environment* is the closest I'll ever get to writing a book with him.

When the editors at Addison-Wesley told me that they wanted to update Rich's book, I thought that there wouldn't be too much to change. Even after 13 years, Rich's work still holds up well. But the UNIX industry is vastly different today from what it was when the book was first published.

- The System V variants are slowly being replaced by Linux. The major system vendors that ship their hardware with their own versions of the UNIX System have either made Linux ports available or announced support for Linux. Solaris is perhaps the last descendant of UNIX System V Release 4 with any appreciable market share.
- After 4.4BSD was released, the Computing Science Research Group (CSRG) from the University of California at Berkeley decided to put an end to its development of the UNIX operating system, but several different groups of volunteers still maintain publicly available versions.
- The introduction of Linux, supported by thousands of volunteers, has made it possible for anyone with a computer to run an operating system similar to the UNIX System, with freely available source code for the newest hardware devices. The success of Linux is something of a curiosity, given that several free BSD alternatives are readily available.
- Continuing its trend as an innovative company, Apple Computer abandoned its old Mac operating system and replaced it with one based on Mach and FreeBSD.

Thus, I've tried to update the information presented in this book to reflect these four platforms.

After Rich wrote *Advanced Programming in the UNIX Environment* in 1992, I got rid of most of my UNIX programmer's manuals. To this day, the two books I keep closest to my desk are a dictionary and a copy of *Advanced Programming in the UNIX Environment*. I hope you find this revision equally useful.

Changes from the First Edition

Rich's work holds up well. I've tried not to change his original vision for this book, but a lot has happened in 13 years. This is especially true with the standards that affect the UNIX programming interface.

Throughout the book, I've updated interfaces that have changed from the ongoing efforts in standards organizations. This is most noticeable in Chapter 2, since its primary topic is standards. The 2001 version of the POSIX.1 standard, which we use in this revision, is much more comprehensive than the 1990 version on which the first edition of this book was based. The 1990 ISO C standard was updated in 1999, and some changes affect the interfaces in the POSIX.1 standard.

A lot more interfaces are now covered by the POSIX.1 specification. The base specifications of the Single UNIX Specification (published by The Open Group, formerly X/Open) have been merged with POSIX.1. POSIX.1 now includes several 1003.1 standards and draft standards that were formerly published separately. Accordingly, I've added chapters to cover some new topics. Threads and multithreaded programming are important concepts because they present a cleaner way for programmers to deal with concurrency and asynchrony.

The socket interface is now part of POSIX.1. It provides a single interface to interprocess communication (IPC), regardless of the location of the process, and is a natural extension of the IPC chapters.

I've omitted most of the real-time interfaces that appear in POSIX.1. These are best treated in a text devoted to real-time programming. One such book appears in the bibliography.

I've updated the case studies in the last chapters to cover more relevant real-world examples. For example, few systems these days are connected to a PostScript printer via a serial or

parallel port. Most PostScript printers today are accessed via a network, so I've changed the case study that deals with PostScript printer communication to take this into account.

The chapter on modem communication is less relevant these days. So that the original material is not lost, however, it is available on the book's Web site in two formats: PostScript (<http://www.apuebook.com/lostchapter/modem.ps>) and PDF (<http://www.apuebook.com/lostchapter/modem.pdf>).

The source code for the examples shown in this book is also available at www.apuebook.com. Most of the examples have been run on four platforms:

1. FreeBSD 5.2.1, a derivative of the 4.4BSD release from the Computer Systems Research Group at the University of California at Berkeley, running on an Intel Pentium processor
2. Linux 2.4.22 (the Mandrake 9.2 distribution), a free UNIX-like operating system, running on Intel Pentium processors
3. Solaris 9, a derivative of System V Release 4 from Sun Microsystems, running on a64-bit UltraSPARC III processor
4. Darwin 7.4.0, an operating environment based on FreeBSD and Mach, supported by Apple Mac OS X, version 10.3, on a PowerPC processor

Stephen A. Rago
Warren, New Jersey
April 2005
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Preface to the First Edition

Introduction

This book describes the programming interface to the Unix system--the system call interface and many of the functions provided in the standard C library. It is intended for anyone writing programs that run under Unix.

Like most operating systems, Unix provides numerous services to the programs that are running -- open a file, read a file, start a new program, allocate a region of memory, get the current time-of-day, and so on. This has been termed the system call interface. Additionally, the standard C library provides numerous functions that are used by almost every C program (format a variable's value for output, compare two strings, etc.).

The system call interface and the library routines have traditionally been described in Sections 2 and 3 of the Unix Programmer's Manual. This book is not a duplication of these sections. Examples and rationale are missing from the Unix Programmer's Manual, and that's what this book provides.

Unix Standards

The proliferation of different versions of Unix during the 1980s has been tempered by the various international standards that were started during the late 1980s. These include the ANSI standard for the C programming language, the IEEE POSIX family (still being developed), and the X/Open portability guide. This book also describes these standards. But instead of just

describing the standards by themselves, we describe them in relation to popular implementations of the standards -- System V Release 4 and the forthcoming 4.4BSD. This provides a real-world description, which is often lacking from the standard itself and from books that describe only the standard.

Organization of the Book

This book is divided into six parts:

An overview and introduction to basic Unix programming concepts and terminology (Chapter 1), with a discussion of the various Unix standardization efforts and different Unix implementations (Chapter 2).

1. I/O--unbuffered I/O (Chapter 3), properties of files and directories (Chapter 4), the standard I/O library (Chapter 5), and the standard system data files (Chapter 6).
2. Processes -- the environment of a Unix process (Chapter 7), process control (Chapter 8), the relationships between different processes (Chapter 9), and signals (Chapter 10).
3. More I/O -- terminal I/O (Chapter 11), advanced I/O (Chapter 12), and daemon processes (Chapter 13).
4. IPC--Interprocess communication (Chapters 14 and 15).
5. Examples--a database library (Chapter 16), communicating with a PostScript printer (Chapter 17), a modem dialing program (Chapter 18), and using pseudo terminals (Chapter 19).

A reading familiarity with C would be beneficial as would some experience using Unix. No prior programming experience with Unix is assumed. This text is intended for programmers familiar with Unix and programmers familiar with some other operating system who wish to learn the details of the services provided by most Unix systems.

Examples in the Text

This book contains many examples--approximately 10,000 lines of source code. All the examples are in the C programming language. Furthermore, these examples are in ANSI C. You should have a copy of the Unix Programmer's Manual for your system handy while reading this book, since reference is made to it for some of the more esoteric and implementation-dependent features.

Almost every function and system call is demonstrated with a small, complete program. This lets us see the arguments and return values and is often easier to comprehend than the use of the function in a much larger program. But since some of the small programs are contrived examples, a few bigger examples are also included (Chapters 16, 17, 18, and 19). These larger examples demonstrate the programming techniques in larger, real-world examples.

Systems Used to Test the Examples

Unfortunately all operating systems are moving targets. Unix is no exception. The following diagram shows the recent evolution of the various versions of System V and 4.xBSD.

4.xBSD are the various systems from the Computer Systems Research Group at the University of California at Berkeley. This group also distributes the BSD Net 1 and BSD Net 2 releases -- publicly available source code from the 4.xBSD systems. SVRx refers to System V Release x

from AT&T. XPG3 is the X/Open Portability Guide, Issue 3, and ANSI C is the ANSI standard for the C programming language. POSIX.1 is the IEEE and ISO standard for the interface to a Unix-like system. We'll have more to say about these different standards and the various versions of Unix in Sections 2.2 and 2.3.

In this text we use the term 4.3+BSD to refer to the Unix system from Berkeley that is somewhere between the BSD Net 2 release and 4.4BSD. At the time of this writing, 4.4BSD was not released, so the system could not be called 4.4BSD. Nevertheless a simple name was needed to refer to this system and 4.3+BSD is used throughout the text.

Most of the examples in this text have been run on four different versions of Unix:

Unix System V/386 Release 4.0 Version 2.0 ("vanilla SVR4") from U.H. Corp. (UHC), on an Intel 80386 processor.

1. 4.3+BSD at the Computer Systems Research Group, Computer Science Division, University of California at Berkeley, on a Hewlett Packard workstation.
2. BSD/386 (a derivative of the BSD Net 2 release) from Berkeley Software Design, Inc., on an Intel 80386 processor. This system is almost identical to what we call 4.3+BSD.
3. SunOS 4.1.1 and 4.1.2 (systems with a strong Berkeley heritage but many System V features) from Sun Microsystems, on a SPARCstation SLC.

Numerous timing tests are provided in the text and the systems used for the test are identified.

W. Richard Stevens
Tucson, Arizona
April 1992

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Users Review

From reader reviews:

Marco Roy:

Have you spare time for the day? What do you do when you have much more or little spare time? That's why, you can choose the suitable activity intended for spend your time. Any person spent their particular spare time to take a move, shopping, or went to the particular Mall. How about open or even read a book eligible Advanced Programming in the UNIX Environment (2nd Edition)? Maybe it is to become best activity for you. You realize beside you can spend your time with your favorite's book, you can more intelligent than before. Do you agree with the opinion or you have different opinion?

Raymond Bryan:

This Advanced Programming in the UNIX Environment (2nd Edition) book is simply not ordinary book, you have after that it the world is in your hands. The benefit you obtain by

reading this book is information inside this publication incredible fresh, you will get information which is getting deeper you read a lot of information you will get. That Advanced Programming in the UNIX Environment (2nd Edition) without we understand teach the one who reading it become critical in imagining and analyzing. Don't possibly be worry Advanced Programming in the UNIX Environment (2nd Edition) can bring if you are and not make your tote space or bookshelves' turn out to be full because you can have it in the lovely laptop even phone. This Advanced Programming in the UNIX Environment (2nd Edition) having great arrangement in word as well as layout, so you will not experience uninterested in reading.

William Luke:

Advanced Programming in the UNIX Environment (2nd Edition) can be one of your nice books that are good idea. We all recommend that straight away because this publication has good vocabulary that can increase your knowledge in vocab, easy to understand, bit entertaining however delivering the information. The copy writer giving his/her effort to get every word into pleasure arrangement in writing Advanced Programming in the UNIX Environment (2nd Edition) however doesn't forget the main position, giving the reader the hottest as well as based confirm resource data that maybe you can be among it. This great information can easily drawn you into brand-new stage of crucial thinking.

John Johnson:

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