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Linux内核设计与实现

（英文版·第3版）

Linux Kernel Development (Third Edition)

（美） Robert Love 著

机械工业出版社
China Machine Press

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Foreword

As the Linux kernel and the applications that use it become more widely used, we are seeing an increasing number of system software developers who wish to become involved in the development and maintenance of Linux. Some of these engineers are motivated purely by personal interest, some work for Linux companies, some work for hardware manufacturers, and some are involved with in-house development projects.

But all face a common problem: The learning curve for the kernel is getting longer and steeper. The system is becoming increasingly complex, and it is very large. And as the years pass, the current members of the kernel development team gain deeper and broader knowledge of the kernel's internals, which widens the gap between them and newcomers.

I believe that this declining accessibility of the Linux source base is already a problem for the quality of the kernel, and it will become more serious over time. Those who care for Linux clearly have an interest in increasing the number of developers who can contribute to the kernel.

One approach to this problem is to keep the code clean: sensible interfaces, consistent layout, "do one thing, do it well," and so on. This is Linus Torvalds' solution.

The approach that I counsel is to liberally apply commentary to the code: words that the reader can use to understand what the coder intended to achieve at the time. (The process of identifying divergences between the intent and the implementation is known as debugging. It is hard to do this if the intent is not known.)

But even code commentary does not provide the broad-sweep view of what a major subsystem is intended to do, and of how its developers set about doing it. This, the starting point of understanding, is what the written word serves best.

Robert Love's contribution provides a means by which experienced developers can gain that essential view of what services the kernel subsystems are supposed to provide, and of how they set about providing them. This will be sufficient knowledge for many people: the curious, the application developers, those who wish to evaluate the kernel's design, and others.

But the book is also a stepping stone to take aspiring kernel developers to the next stage, which is making alterations to the kernel to achieve some defined objective. I would encourage aspiring developers to get their hands dirty: The best way to understand a part of the kernel is to make changes to it. Making a change forces the developer to a level of understanding which merely reading the code does not provide. The serious kernel developer will join the development mailing lists and will interact with other developers. This interaction is the primary means by which kernel contributors learn

and stay abreast. Robert covers the mechanics and culture of this important part of kernel life well.

Please enjoy and learn from Robert's book. And should you decide to take the next step and become a member of the kernel development community, consider yourself welcomed in advance. We value and measure people by the usefulness of their contributions, and when you contribute to Linux, you do so in the knowledge that your work is of small but immediate benefit to tens or even hundreds of millions of human beings. This is a most enjoyable privilege and responsibility.

Andrew Morton

Preface

When I was first approached about converting my experiences with the Linux kernel into a book, I proceeded with trepidation. What would place my book at the top of its subject? I was not interested unless I could do something special, a best-in-class work.

I realized that I could offer a unique approach to the topic. My job is hacking the kernel. My hobby is hacking the kernel. My love is hacking the kernel. Over the years, I have accumulated interesting anecdotes and insider tips. With my experiences, I could write a book on how to hack the kernel and—just as important—how *not* to hack the kernel. First and foremost, this is a book about the design and implementation of the Linux kernel. This book's approach differs from would-be competitors, however, in that the information is given with a slant to learning enough to actually get work done—and getting it done right. I am a pragmatic engineer and this is a practical book. It should be fun, easy to read, and useful.

I hope that readers can walk away from this work with a better understanding of the rules (written and unwritten) of the Linux kernel. I intend that you, fresh from reading this book and the kernel source code, can jump in and start writing useful, correct, clean kernel code. Of course, you can read this book just for fun, too.

That was the first edition. Time has passed, and now we return once more to the fray. This third edition offers quite a bit over the first and second: intense polish and revision, updates, and many fresh sections and all new chapters. This edition incorporates changes in the kernel since the second edition. More important, however, is the decision made by the Linux kernel community to not proceed with a 2.7 development kernel in the near to mid-term.[1] Instead, kernel developers plan to continue developing and stabilizing the 2.6 series. This decision has many implications, but the item of relevance to this book is that there is quite a bit of staying power in a contemporary book on the 2.6 Linux kernel. As the Linux kernel matures, there is a greater chance of a snapshot of the kernel remaining representative long into the future. This book functions as the canonical documentation for the kernel, documenting it with both an understanding of its history and an eye to the future.

Using This Book

Developing code in the kernel does not require genius, magic, or a bushy Unix-hacker beard. The kernel, although having some interesting rules of its own, is not much different from any other large software endeavor. You need to master many details—as with any big project—but the differences are quantitative, not qualitative.

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[1] *This decision was made in the summer of 2004 at the annual Linux Kernel Developers Summit in Ottawa, Canada. Your author was an invited attendee.*

It is imperative that you utilize the source. The open availability of the source code for the Linux system is a rare gift that you must not take for granted. It is not sufficient *only* to read the source, however. You need to dig in and change some code. Find a bug and fix it. Improve the drivers for your hardware. Add some new functionality, even if it is trivial. Find an itch and scratch it! Only when you *write* code will it all come together.

Kernel Version

This book is based on the 2.6 Linux kernel series. It does not cover older kernels, except for historical relevance. We discuss, for example, how certain subsystems are implemented in the 2.4 Linux kernel series, as their simpler implementations are helpful teaching aids. Specifically, this book is up to date as of Linux kernel version 2.6.34. Although the kernel is a moving target and no effort can hope to capture such a dynamic beast in a timeless manner, my intention is that this book is relevant for developers and users of both older and newer kernels.

Although this book discusses the 2.6.34 kernel, I have made an effort to ensure the material is factually correct with respect to the 2.6.32 kernel as well. That latter version is sanctioned as the "enterprise" kernel by the various Linux distributions, ensuring we will continue to see it in production systems and under active development for many years. (2.6.9, 2.6.18, and 2.6.27 were similar "long-term" releases.)

Audience

This book targets Linux developers and users who are interested in understanding the Linux kernel. It is *not* a line-by-line commentary of the kernel source. Nor is it a guide to developing drivers or a reference on the kernel API. Instead, the goal of this book is to provide enough information on the design and implementation of the Linux kernel that a sufficiently accomplished programmer can begin developing code in the kernel. Kernel development can be fun and rewarding, and I want to introduce the reader to that world as readily as possible. This book, however, in discussing both theory and application, should appeal to readers of both academic and practical persuasions. I have always been of the mind that one needs to understand the theory to understand the application, but I try to balance the two in this work. I hope that whatever your motivations for understanding the Linux kernel, this book explains the design and implementation sufficiently for your needs.

Thus, this book covers both the usage of core kernel systems and their design and implementation. I think this is important and deserves a moment's discussion. A good example is Chapter 8, "Bottom Halves and Deferring Work," which covers a component of device drivers called bottom halves. In that chapter, I discuss both the design and implementation of the kernel's bottom-half mechanisms (which a core kernel developer or academic might find interesting) and how to actually use the exported interfaces to implement your own bottom half (which a device driver developer or casual hacker can find pertinent). I believe all groups can find both discussions relevant. The core kernel

developer, who certainly needs to understand the inner workings of the kernel, should have a good understanding of how the interfaces are actually used. At the same time, a device driver writer can benefit from a good understanding of the implementation behind the interface.

This is akin to learning some library's API versus studying the actual implementation of the library. At first glance, an application programmer needs to understand only the API—it is often taught to treat interfaces as a black box. Likewise, a library developer is concerned only with the library's design and implementation. I believe, however, both parties should invest time in learning the other half. An application programmer who better understands the underlying operating system can make much greater use of it. Similarly, the library developer should not grow out of touch with the reality and practicality of the applications that use the library. Consequently, I discuss both the design and usage of kernel subsystems, not only in hopes that this book will be useful to either party, but also in hopes that the *whole* book is useful to both parties.

I assume that the reader knows the C programming language and is familiar with Linux systems. Some experience with operating system design and related computer science topics is beneficial, but I try to explain concepts as much as possible—if not, the Bibliography includes some excellent books on operating system design.

This book is appropriate for an undergraduate course introducing operating system design as the *applied* text if accompanied by an introductory book on theory. This book should fare well either in an advanced undergraduate course or in a graduate-level course without ancillary material.

Third Edition Acknowledgments

Like most authors, I did not write this book in a cave, which is a good thing, because there are bears in caves. Consequently many hearts and minds contributed to the completion of this manuscript. Although no list could be complete, it is my sincere pleasure to acknowledge the assistance of many friends and colleagues who provided encouragement, knowledge, and constructive criticism.

First, I would like to thank my team at Addison–Wesley and Pearson who worked long and hard to make this a better book, particularly Mark Taber for spearheading this third edition from conception to final product; Michael Thurston, development editor; and Tonya Simpson, project editor.

A special thanks to my technical editor on this edition, Robert P. J. Day. His insight, experience, and corrections improved this book immeasurably. Despite his sterling effort, however, any remaining mistakes remain my own. I have the same gratitude to Adam Belay, Zack Brown, Martin Pool, and Chris Rivera, whose excellent technical editing efforts on the first and second editions still shine through.

Many fellow kernel developers answered questions, provided support, or simply wrote code interesting enough on which to write a book. They include Andrea Arcangeli, Alan Cox, Greg Kroah-Hartman, Dave Miller, Patrick Mochel, Andrew Morton, Nick Piggin, and Linus Torvalds.

A big thank you to my colleagues at Google, the most creative and intelligent group with which I have ever had the pleasure to work. Too many names would fill these pages if I listed them all, but I will single out Alan Blount, Jay Crim, Chris Danis, Chris DiBona, Eric Flatt, Mike Lockwood, San Mehat, Brian Rogan, Brian Swetland, Jon Trowbridge, and Steve Vinter for their friendship, knowledge, and support.

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Finally, thank you to my parents for so much, particularly my well-proportioned ears. Happy Hacking!

Robert Love
Boston

About the Author

Robert Love is an open source programmer, speaker, and author who has been using and contributing to Linux for more than 15 years. Robert is currently senior software engineer at Google, where he was a member of the team that developed the Android mobile platform's kernel. Prior to Google, he was Chief Architect, Linux Desktop, at Novell. Before Novell, he was a kernel engineer at MontaVista Software and Ximian.

Robert's kernel projects include the preemptive kernel, the process scheduler, the kernel events layer, inotify, VM enhancements, and several device drivers.

Robert has given numerous talks on and has written multiple articles about the Linux kernel. He is a contributing editor for *Linux Journal*. His other books include *Linux System Programming* and *Linux in a Nutshell*.

Robert received a B.A. degree in mathematics and a B.S. degree in computer science from the University of Florida. He lives in Boston.

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