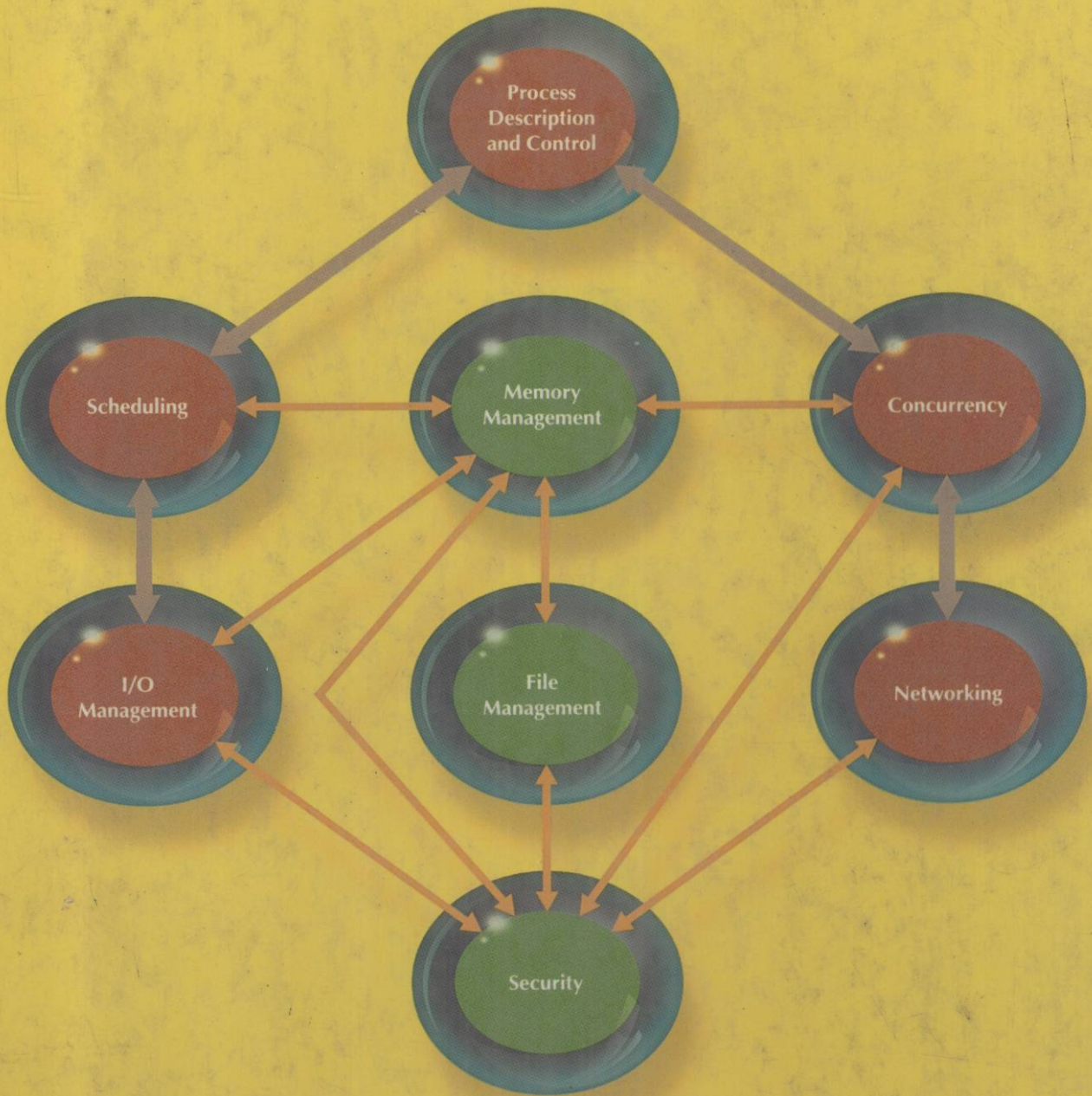
OPERATING SYSTEMS

WILLIAM STALLINGS



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OPERATING SYSTEMS

To Tricia,
the bravest person in the world

Preface

Objectives

This book is about the concepts, structure, and mechanisms of operating systems. Its purpose is to present, as clearly and completely as possible, the nature and characteristics of modern-day operating systems.

This task is a challenging one for several reasons.

First, there is a tremendous range and variety of computer systems for which operating systems are designed. These include single-user workstations and personal computers, medium-sized shared systems, large mainframe and supercomputers, and specialized machines such as real-time systems. The variety is not just in the capacity and speed of machines, but in applications and system support requirements. Second, the rapid pace of change that has always characterized computer systems continues with no letup. A number of key areas in operating-system design are of recent origin, and research into these and other new areas continues.

In spite of this variety and pace of change, certain fundamental concepts apply consistently throughout. To be sure, the application of these concepts depends on the current state of technology and the particular application requirements. The intent of this book is to provide a thorough discussion of the fundamentals of operating-system design, and to relate these to contemporary design issues and to current directions in the development of operating systems.

The object is to provide the reader with a solid understanding of the key mechanisms of modern operating systems, the types of design trade-offs and decisions involved in OS design, and the context within which the operating system functions (hardware, other system programs, application programs, interactive users).

The Process

The concept of the process is central to the study of operating systems. While all books on the subject deal with this topic, no other leading text devotes a major section to introducing and explaining the basic principles of processes.

In this book, Chapter 3 is devoted to this task. The result is a solid foundation for examining the many issues addressed in later chapters.

Recent Developments in Operating System Design

In addition to providing coverage of the fundamentals of operating systems, this book examines the most important recent developments in OS design. Among the topics covered:

- *Threads:* The concept of process is more complex and subtle than usually presented and in fact embodies two separate and potentially independent concepts: one relating to resource ownership and one relating to execution. This distinction has led to the development in some operating systems of a construct known as the thread.
- *Real time systems:* In recent years, real-time computing has come to be viewed as an important emerging discipline in computer science and engineering. The operating system, and in particular the scheduler, is perhaps the most important component of a real-time system.
- *Multiprocessor scheduling:* Traditionally, there has been little difference between the scheduling approaches taken on multiprogrammed uniprocessors and multiprocessor systems. With the increasing interest in the use of threads and in parallel programming, multiprocessor scheduling has become an area of intense study and development.
- *Distributed systems:* With the increasing availability of inexpensive yet powerful personal computers and minicomputers, there has been an increasing trend toward distributed data processing (DDP). With DDP, processors, data, and other aspects of a data processing system may be dispersed within an organization. Many of the OS design issues covered in this book take on added complexity in a distributed environment.
- *Process migration:* Process migration is the ability to move an active process from one machine to another; it has become an increasingly "hot" topic in distributed operating systems. Interest in this concept grew out of research into ways to do load balancing across multiple networked systems, although the application of the concept now extends beyond that one area. Until recently, a number of observers felt that process migration was impractical. Such assessments have proved too pessimistic. New implementations, including those in commercial products, have fueled a continuing interest and new developments in this area.
- *Security:* Security has long been a concern in the design of operating systems. However, the design approaches to security have continued to evolve as the threats to security have evolved. Examples of areas of threat that present new and more complex difficulties include viruses and attacks on distributed operting systems. An example of a new approach to coping with these threats is the concept of a trusted system.

Example Systems

This text is intended to acquaint the reader with the design principles and implementation issues of contemporary operating systems. Accordingly, a purely conceptual or theoretical treatment would be inadequate. In order to illustrate the concepts and to tie them to real-world design choices that must be made, three operating systems have been chosen as running examples:

- *OS/2:* A single-user, multitasking operating system for the IBM PS/2 and compatible systems. It is one of the few truly new operating systems that has been essentially designed from scratch (although it includes an MS-DOS compatibility mode). As such, it is in a position to incorporate in a clean fashion the latest developments in operating system technology.
- *UNIX:* A multiuser operating system, originally intended for minicomputers, but implemented on a wide range of machines from powerful microcomputers to supercomputers.
- *MVS:* The top-of-the-line operating system for IBM mainframes, and perhaps the most complex operating system ever developed. It provides both batch and timesharing capabilities.

These three systems were chosen because of their relevance and representativeness. Most personal computer operating systems on new machines are single-user multitasking systems, with OS/2 becoming the market leader. UNIX has become the dominant operating system on a wide variety of workstations and multiuser systems. MVS is the most widely used mainframe operating system. Thus, most readers will be exposed to one or more of these operating systems by the time they use this book or within a few years of doing so.

As with the technique used in the author's *Computer Organization and Architecture,* the discussion of the example systems is distributed throughout the text rather than assembled as a single chapter or appendix. Thus, during the discussion of virtual memory, the page replacement algorithm of each example system is described, and the motivation for the individual design choices is discussed. With this approach, the design concepts discussed in a given chapter are immediately reinforced with real-world examples.

Intended Audience

The book is intended for both an academic and a professional audience. As a textbook, it is intended as a one-semester undergraduate course in operating systems for computer science, computer engineering, and electrical engineering majors. It covers the topics in Subject Area 5 of the IEEE Model Program in Computer Science and Engineering and also covers the OS-related topics in CS6 and CS10 of the ACM Recommendations for the Undergraduate Program in Computer Science. It also covers all of the topics in the operating systems topic area of the ACM/IEEE Joint Computing Curricula 1991.

The book also serves as a basic reference volume and is suitable for self-study.

Plan of the Text

The organization of the chapters is as follows:

1. *Computer system overview:* Provides an overview of computer architecture and organization, with emphasis on topics that relate to operating system design.
2. *Operating system overview:* Provides an overview of the remainder of the book.
3. *Process description and control:* Presents the concept of a process and examines the data structures used by the operating system to control processes. The related concepts of threads and sessions are also discussed.
4. *Concurrency:* Examines the key aspects of concurrency on a single system, with emphasis on issues of mutual exclusion and deadlock.
5. *Memory management:* Provides a comprehensive survey of techniques for memory management.
6. *Scheduling:* Provides a comparative discussion of various approaches to process scheduling. The unique requirements of multiprocessors and real-time systems are examined.
7. *I/O management and disk scheduling:* Examines the issues involved in OS control of the I/O function. Special attention is devoted to disk I/O, which is the key to system performance.
8. *File management:* Provides an overview of file management, with an emphasis on those aspects that are usually implemented as part of the operating system or are closely tied to the operating system.
9. *Networking and distributed processing:* Examines the major trends in this area, including the OSI model, the use of network servers, and distributed operating systems.
10. *Security:* Provides a survey of threats and mechanisms for providing computer and network security.

A. *Queuing analysis:* An appendix provides a practical guide to the use of queuing analysis to model performance.

In addition, the book includes an extensive glossary, a list of frequently-used acronyms, and a bibliography. Each chapter includes problems and suggestions for further reading.

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