Software Engineering

A PRACTITIONER'S APPROACH

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Software Engineering

A PRACTITIONER'S APPROACH

FIFTH EDITION

Roger S. Pressman, Ph.D.

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To my parents

ABOUT THE AUTHOR

Roger S. Pressman is an internationally recognized authority in software process improvement and software engineering technologies. For over three decades, he has worked as a software engineer, a manager, a professor, an author, and a consultant, focusing on software engineering issues.

As an industry practitioner and manager, Dr. Pressman worked on the development of CAD/CAM systems for advanced engineering and manufacturing applications. He has also held positions with responsibility for scientific and systems programming.

After receiving a Ph.D. in engineering from the University of Connecticut, Dr. Pressman moved to academia where he became Bullard Associate Professor of Computer Engineering at the University of Bridgeport and director of the university's Computer-Aided Design and Manufacturing Center.

Dr. Pressman is currently president of R.S. Pressman & Associates, Inc., a consulting firm specializing in software engineering methods and training. He serves as principle consultant, helping companies establish effective software engineering practices. He also designed and developed the company's software engineering training and process improvement products—*Essential Software Engineering,* a complete video curriculum that is among the industry's most comprehensive treatments of the subject, and *Process Advisor,* a self-directed system for software engineering process improvement. Both products are used by hundreds of companies worldwide.

Dr. Pressman has written many technical papers, is a regular contributor to industry periodicals, and is author of six books. In addition to *Software Engineering: A Practitioner's Approach,* he has written *A Manager's Guide to Software Engineering* (McGraw-Hill), an award-winning book that uses a unique Q&A format to present management guidelines for instituting and understanding software engineering technology; *Making Software Engineering Happen* (Prentice-Hall), the first book to address the critical management problems associated with software process improvement; and *Software Shock* (Dorset House), a treatment that focuses on software and its impact on business and society. Dr. Pressman is on the Editorial Boards of *IEEE Software* and the *Cutter IT Journal,* and for many years, was editor of the "Manager" column in *IEEE Software.*

Dr. Pressman is a well-known speaker, keynoting a number of major industry conferences. He has presented tutorials at the International Conference on Software Engineering and at many other industry meetings. He is a member of the ACM, IEEE, and Tau Beta Pi, Phi Kappa Phi, Eta Kappa Nu, and Pi Tau Sigma.

CONTENTS AT A GLANCE

TABLE OF CONTENTS

CHAPTER 13 DESIGN CONCEPTS AND PRINCIPLES 335

CHAPTER 14 ARCHITECTURAL DESIGN 365

PREFACE

When a computer software succeeds—when it meets the needs of the people who use it, when it performs flawlessly over a long period of time, when it is easy to modify and even easier to use—it can and does change things for the better. But when software fails—when its users are dissatisfied, when it is error prone, when it is difficult to change and even harder to use—bad things can and do happen. We all want to build software that makes things better, avoiding the bad things that lurk in the shadow of failed efforts. To succeed, we need discipline when software is designed and built. We need an engineering approach.

In the 20 years since the first edition of this book was written, software engineering has evolved from an obscure idea practiced by a relatively small number of zealots to a legitimate engineering discipline. Today, it is recognized as a subject worthy of serious research, conscientious study, and tumultuous debate. Throughout the industry, *software engineer* has replaced *programmer* as the job title of preference. Software process models, software engineering methods, and software tools have been adopted successfully across a broad spectrum of industry applications.

Although managers and practitioners alike recognize the need for a more disciplined approach to software, they continue to debate the manner in which discipline is to be applied. Many individuals and companies still develop software haphazardly, even as they build systems to service the most advanced technologies of the day. Many professionals and students are unaware of modern methods. And as a result, the quality of the software that we produce suffers and bad things happen. In addition, debate and controversy about the true nature of the software engineering approach continue. The status of software engineering is a study in contrasts. Attitudes have changed, progress has been made, but much remains to be done before the discipline reaches full maturity.

The fifth edition of *Software Engineering: A Practitioner's Approach* is intended to serve as a guide to a maturing engineering discipline. The fifth edition, like the four editions that preceded it, is intended for both students and practitioners, retaining its appeal as a guide to the industry professional and a comprehensive introduction to the student at the upper level undergraduate or first year graduate level. The format and style of the fifth edition have undergone significant change, making the presentation more reader-friendly and the content more easily accessible.

The fifth edition is considerably more than a simple update. The book has been revised to accommodate the dramatic growth in the field and to emphasize new and important software engineering practices. In addition, a comprehensive Web site has been developed to complement the content of the book. The Web site, which I call

SepaWeb, can be found at **http://www.mhhe.com/pressman.** Designed to be used in conjunction with the fifth edition of *Software Engineering: A Practitioner's Approach,* SepaWeb provides a broad array of software engineering resources that will benefit instructors, students, and industry professionals.

Like all Web sites, SepaWeb will evolve over time, but the following major content areas will always be present: (1) a broad array of *instructor resources* including a comprehensive on-line *Instructor's Guide* and supplementary teaching materials (e.g., slide presentations to supplement lectures, video-based instructional aids); (2) a wide variety of *student resources* including an extensive on-line learning center (encompassing study guides, Web-based resources, and self-tests), an evolving collection of "tiny tools," a case study, and additional supplementary content; and (3) a detailed collection of *professional resources* including outlines (and samples of) software engineering documents and other work products, a useful set of software engineering checklists, a catalog of software engineering (CASE) tools, a comprehensive collection of Web-based resources, and an "adaptable process model" that provides a detailed task breakdown of the software engineering process. In addition, SepaWeb will contain other goodies that are currently in development.

The 32 chapters of the fifth edition have been organized into five parts. This has been done to compartmentalize topics and assist instructors who may not have the time to complete the entire book in one term. Part One, The Product and the Process, presents an introduction to the software engineering milieu. It is intended to introduce the subject matter, and more important, to present concepts that will be necessary for later chapters. Part Two, Managing Software Projects, presents topics that are relevant to those who plan, manage, and control a software development project. Part Three, Conventional Methods for Software Engineering, presents the classical analysis, design, and testing methods that some view as the "conventional" school of software engineering. Part Four, Object-Oriented Software Engineering, presents object-oriented methods across the entire software engineering process, including analysis, design, and testing. Part Five, Advanced Software Engineering Topics, presents dedicated chapters that address formal methods, cleanroom software engineering, component-based software engineering, client/server software engineering, Web engineering, reengineering, and CASE.

The five-part organization of the fifth edition enables an instructor to "cluster" topics based on available time and student need. An entire one-term course can be built around one or more of the five parts. For example, a "design course" might emphasize only Part Three or Part Four; a "methods course" might present selected chapters in Parts Three, Four, and Five. A "management course" would stress Parts One and Two. By organizing the fifth edition in this way, I attempted to provide an instructor with a number of teaching options. SepaWeb can and should be used to supplement the content that is chosen from the book.

An *Instructor's Guide* for *Software Engineering: A Practitioner's Approach* is available from SepaWeb. The *Instructor's Guide* presents suggestions for conducting var-

ious types of software engineering courses, recommendations for a variety of software projects to be conducted in conjunction with a course, solutions to selected problems, and a number of teaching aids.

A comprehensive video curriculum, *Essential Software Engineering,* is available to complement this book. The video curriculum has been designed for industry training and has been modularized to enable individual software engineering topics to be presented on an as-needed, when-needed basis. Further information on the video can be obtained by mailing the request card at the back of this book.[1]

My work on the five editions of *Software Engineering: A Practitioner's Approach* has been the longest continuing technical project of my life. Even when the writing stops, information extracted from the technical literature continues to be assimilated and organized. For this reason, my thanks to the many authors of books, papers, and articles as well as a new generation of contributors to electronic media (newsgroups, e-newsletters, and the World Wide Web) who have provided me with additional insight, ideas, and commentary over the past 20 years. Many have been referenced within the pages of each chapter. All deserve credit for their contribution to this rapidly evolving field. I also wish to thank the reviewers of the fifth edition: Donald H. Kraft, Louisiana State University; Panos E. Livadas, University of Florida; Joseph Lambert, Pennsylvania State University; Kenneth L. Modesitt, University of Michigan—Dearborn; and, James Purtilo, University of Maryland. Their comments and criticism have been invaluable. Special thanks and acknowledgement also go to Bruce Maxim of the University of Michigan—Dearborn, who assisted me in developing the Web site that accompanies this book. Bruce is responsible for much of its design and pedagogical content.

The content of the fifth edition of *Software Engineering: A Practitioner's Approach* has been shaped by industry professionals, university professors, and students who have used earlier editions of the book and have taken the time to communicate their suggestions, criticisms, and ideas. My thanks to each of you. In addition, my personal thanks go to our many industry clients worldwide, who certainly teach me as much or more than I can teach them.

As the editions of this book have evolved, my sons, Mathew and Michael, have grown from boys to men. Their maturity, character, and success in the real world have been an inspiration to me. Nothing has filled me with more pride. And finally, to Barbara, my love and thanks for encouraging still another edition of "the book."

Roger S. Pressman

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USING THIS BOOK

The fifth edition of *Software Engineering: A Practitioner's Approach* (SEPA) has been redesigned to enhance your reading experience and to provide integrated links to the SEPA Web site, http://www.mhhe.com/pressman/. SepaWeb contains a wealth of useful supplementary information for readers of the book and a broad array of resources (e.g., an *Instructor's Guide,* classroom slides, and video supplements) for instructors who have adopted SEPA for classroom use.

A comprehensive video curriculum, *Essential Software Engineering,* is available to complement this book. The video curriculum has been designed for industry training and has been modularized to enable individual software engineering topics to be presented on an as-needed, when-needed basis. Further information on the video can be obtained by mailing the request card at the back of this book.[1]

Throughout the book, you will encounter marginal icons that should be interpreted in the following manner:

Used to emphasize an important point in the body of the text.

The **keypoint** icon will help you to find important points quickly.

Practical advice from the real world of software engineering.

The **advice** icon provides pragmatic guidance that can help you make the right decision or avoid common problems while building software.

Where can I find the answer?

The **question mark** icon asks common questions that are answered in the body of the text.

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Provides an important cross reference within the book.

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A selected topic

The **SepaWeb** pointer indicates that further information about the noted topic is available at the SEPA Web site.

The **SepaWeb.checklists** icon points you to detailed checklists that will help you to assess the software engineering work you're doing and the work products you produce.

The **SepaWeb.documents** icon points you to detailed document outlines, descriptions and examples contained within the SEPA Web site.

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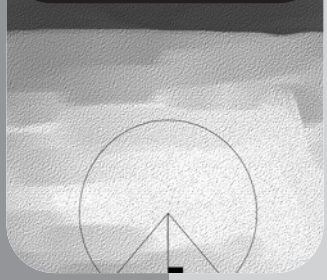
PART

One



THE PRODUCT AND THE PROCESS

In this part of *Software Engineering: A Practitioner's Approach,* you'll learn about the product that is to be engineered and the process that provides a framework for the engineering technology. The following questions are addressed in the chapters that follow:

- What is computer software . . . really?
- Why do we struggle to build high-quality computer-based systems?
- How can we categorize application domains for computer software?
- What myths about software still exist?
- What is a "software process"?
- Is there a generic way to assess the quality of a process?
- What process models can be applied to software development?
- How do linear and iterative process models differ?
- What are their strengths and weaknesses?
- What advanced process models have been proposed for software engineering work?

Once these questions are answered, you'll be better prepared to understand the management and technical aspects of the engineering discipline to which the remainder of this book is dedicated.