

# **SpringerBriefs in Computer Science**

## **Series editors**

Stan Zdonik, Brown University, Providence, Rhode Island, USA

Shashi Shekhar, University of Minnesota, Minneapolis, Minnesota, USA

Xindong Wu, University of Vermont, Burlington, Vermont, USA

Lakhmi C. Jain, University of South Australia, Adelaide, South Australia, Australia

David Padua, University of Illinois Urbana-Champaign, Urbana, Illinois, USA

Xuemin Sherman Shen, University of Waterloo, Waterloo, Ontario, Canada

Borko Furht, Florida Atlantic University, Boca Raton, Florida, USA

V. S. Subrahmanian, University of Maryland, College Park, Maryland, USA

Martial Hebert, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA

Katsushi Ikeuchi, University of Tokyo, Tokyo, Japan

Bruno Siciliano, Università di Napoli Federico II, Napoli, Italy

Sushil Jajodia, George Mason University, Fairfax, Virginia, USA

Newton Lee, Newton Lee Laboratories, LLC, Burbank, California, USA

SpringerBriefs present concise summaries of cutting-edge research and practical applications across a wide spectrum of fields. Featuring compact volumes of 50 to 125 pages, the series covers a range of content from professional to academic.

Typical topics might include:

- A timely report of state-of-the art analytical techniques
- A bridge between new research results, as published in journal articles, and a contextual literature review
- A snapshot of a hot or emerging topic
- An in-depth case study or clinical example
- A presentation of core concepts that students must understand in order to make independent contributions

Briefs allow authors to present their ideas and readers to absorb them with minimal time investment. Briefs will be published as part of Springer's eBook collection, with millions of users worldwide. In addition, Briefs will be available for individual print and electronic purchase. Briefs are characterized by fast, global electronic dissemination, standard publishing contracts, easy-to-use manuscript preparation and formatting guidelines, and expedited production schedules. We aim for publication 8–12 weeks after acceptance. Both solicited and unsolicited manuscripts are considered for publication in this series.

More information about this series at <http://www.springer.com/series/10028>

Sandeep Kumar · Santosh Singh Rathore

# Software Fault Prediction

A Road Map

Sandeep Kumar  
Department of Computer Science  
and Engineering  
Indian Institute of Technology Roorkee  
Roorkee  
India

Santosh Singh Rathore  
Department of Computer Science  
and Engineering  
National Institute of Technology Jalandhar  
Jalandhar  
India

ISSN 2191-5768 ISSN 2191-5776 (electronic)  
SpringerBriefs in Computer Science  
ISBN 978-981-10-8714-1 ISBN 978-981-10-8715-8 (eBook)  
<https://doi.org/10.1007/978-981-10-8715-8>

Library of Congress Control Number: 2018942190

© The Author(s) 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd. part of Springer Nature  
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

# Preface

Software quality assurance (SQA) is a vital and foremost important task to build robust software and to ensure that the developed software meets the standardized quality specifications. There are many parameters/measurements used to measure the quality of the software system. One such measure is the fault-proneness information of the software modules. The presence of faults not only reduces the quality of the software but also increases the development cost of the system. Thus, ensuring lower faults in software system ensures a higher quality of the software. Software fault prediction (SFP) is one such activity, which is used to predict the fault-proneness of the software system prior to the testing process. A large number of software fault prediction models can be found in the literature. Most of these models have used the historical software data, the previously revealed software faults, and metric information to predict the fault-proneness of the software modules. In general, the developed fault prediction model is used to predict that whether a software module is faulty or non-faulty. This book is focused on exploring the use of software fault prediction in building reliable and robust software systems. First, we introduce the basic concepts related to software fault prediction process and discuss its generalized architecture. We also discuss different types of fault prediction models presented in the literature. Subsequently, we discuss different works presented earlier for predicting software modules being faulty or non-faulty. At last, we present an evaluation of different techniques for the software fault prediction and discuss their results. This book also covers the details of the software fault datasets and discusses their different issues with respect to software fault prediction. In addition to various important works reported in this area, some of reported works in this domain are also summarized. The book has been organized as follows. Chapter 1 introduces the basic concepts of software fault prediction and various terminologies. Chapter 2 explains the generalized architecture of software fault prediction process and discusses its different components. Chapter 3 provides the details of types of fault prediction models and discusses the state-of-the-art literature of each model. Chapter 4 describes the software fault datasets and different issues of fault datasets when building fault prediction models. Chapter 5 presents an empirical study to evaluate various fault prediction techniques with reference to

binary class prediction. Chapter 6 presents another study evaluating the techniques for the prediction of number of faults in the software modules. The book concludes with Chap. 7, which provides the summary of the discussed works. The primary contribution of the book lies in presenting a single source of information for software engineers and researchers for learning about the area of software fault prediction. The book can also work as an initial source of information for starting research in this domain. In addition, the book can be useful to the experienced researchers in getting summary of latest work reported in this area. We are hopeful that the book will not only provide a good introductory reference but will also give the readers a breadth and depth of this topic.

Roorkee, India  
Jalandhar, India

Sandeep Kumar  
Santosh Singh Rathore

# Acknowledgements

First, I would like to extend my sincere gratitude to the Almighty God. I also express my thanks to the many people who provided their support in writing this book, either directly or indirectly. I thank Dr. Sandeep Kumar, for the impetus to write this book. I want to acknowledge my sisters and parents for their blessing and persistent backing. I thank all my friends and colleagues for being a source of inspiration and love throughout my journey. I want to thank the anonymous reviewers for proofreading the chapters and the publishing team.

—Santosh Singh Rathore

I would like to express my sincere thanks to my institute, Indian Institute of Technology Roorkee, India, for providing me a healthy and conducive working environment. I am also thankful to the faculty members of the Department of Computer Science and Engineering, Indian Institute of Technology Roorkee, India, for their constant support and encouragement. I am especially thankful to some of my colleagues, who are more like friends and give me constant support. I am also thankful to Prof. R. B. Mishra of the Indian Institute of Technology, Banaras Hindu University, India, for his guidance. I am grateful to the editor and the publication team of the Springer for their constant cooperation in writing the book. I am really thankful to my wife, sisters, brother, parents-in-law, and my lovely daughter Aastha, who is my life, for their love and blessings. I have no words to mention the support, patience, and sacrifice of my parents. I dedicate this book to God and to my family.

—Sandeep Kumar

# Contents

- 1 Introduction . . . . . 1**
  - 1.1 Software Faults, Errors, and Failure Terminologies . . . . . 2
  - 1.2 Benefits of Software Fault Prediction . . . . . 3
  - 1.3 Contribution and Organization of the Book . . . . . 4
  - 1.4 Summary . . . . . 5
  - References . . . . . 5
- 2 Software Fault Prediction Process . . . . . 7**
  - 2.1 Architecture of Software Fault Prediction . . . . . 7
  - 2.2 Components of Software Fault Prediction . . . . . 9
    - 2.2.1 Software Fault Dataset . . . . . 9
  - 2.3 Summary . . . . . 20
  - References . . . . . 20
- 3 Types of Software Fault Prediction . . . . . 23**
  - 3.1 Binary Class Classification of Software Faults . . . . . 23
  - 3.2 Prediction of Number of Faults . . . . . 25
  - 3.3 Cross-Project Software Fault Prediction . . . . . 26
  - 3.4 Just-in-Time Software Fault Prediction . . . . . 28
  - 3.5 Summary . . . . . 29
  - References . . . . . 29
- 4 Software Fault Dataset . . . . . 31**
  - 4.1 Description of Software Fault Dataset . . . . . 32
  - 4.2 Fault Dataset Repositories . . . . . 34
  - 4.3 Issues with Software Fault Datasets . . . . . 35
  - 4.4 Summary . . . . . 37
  - References . . . . . 37

<b>5</b>	<b>Evaluation of Techniques for Binary Class Classification</b>	<b>39</b>
5.1	Description of Different Fault Prediction Techniques	39
5.2	Performance Evaluation Measures	41
5.3	Evaluation of the Fault Prediction Techniques	42
5.3.1	Software Fault Datasets	42
5.3.2	Experimental Setup	43
5.3.3	Experiment Execution	43
5.3.4	Results and Analysis	45
5.4	Summary	56
	References	56
<b>6</b>	<b>Evaluation of Techniques for the Prediction of Number of Faults</b>	<b>59</b>
6.1	Description of the Fault Prediction Techniques	59
6.2	Performance Evaluation Measures	61
6.3	Evaluation of the Techniques for the Prediction of Number of Faults	62
6.3.1	Software Fault Datasets	62
6.3.2	Experimental Setup	62
6.3.3	Results and Analysis	63
6.4	Summary	65
	References	66
<b>7</b>	<b>Conclusions</b>	<b>67</b>
	<b>Closing Remarks</b>	<b>69</b>
	<b>Index</b>	<b>71</b>

## About the Authors

**Sandeep Kumar** (SMIEEE'17) is currently working as an assistant professor in the Department of Computer Science and Engineering, Indian Institute of Technology (IIT) Roorkee, India. He has supervised 3 Ph.D. theses, about 30 master dissertations, about 15 undergraduate projects, and is currently supervising 4 Ph.D. students. He has published more than 45 research papers in international/national journals and conferences and has also written book/chapters with Springer, USA, and IGI Publications, USA. He has also filed two patents for his work done along with his students. He is the member of board of examiners and board of studies of various universities and institutions. He has collaborations in industry and academia. He is currently handling multiple national and international research/consultancy projects. He has received Young Faculty Research Fellowship Award from MeitY (Government of India), NSF/TCPP Early Adopter Award 2014 and 2015, ITS Travel Award 2011 and 2013, and others. He is the member of ACM and senior member of IEEE. His name has also been enlisted in major directories such as Marquis Who's Who and IBC. His areas of interest include semantic Web, Web services, and software engineering. Email: sandeepkumargarg@gmail.com, sgargfec@iitr.ac.in

**Santosh Singh Rathore** did his Ph.D. from the Department of Computer Science and Engineering, Indian Institute of Technology (IIT) Roorkee, India. He received his master's degree (M.Tech.) from the Indian Institute of Information Technology Design and Manufacturing (IIITDM), Jabalpur, India. He is currently working as an assistant professor in the Department of Computer Science and Engineering, National Institute of Technology (NIT) Jalandhar, India. His research interests are software fault prediction, software quality assurance, empirical software engineering, object-oriented software development, and object-oriented metrics. He has published research papers in various refereed journals and international conferences. Email: santosh.srathore@gmail.com