

SpringerBriefs in Computer Science

Series Editors

Stan Zdonik, Brown University, Providence, RI, USA

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

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

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

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

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

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

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

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

Katsushi Ikeuchi, University of Tokyo, Tokyo, Japan

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

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

Newton Lee, Institute for Education, Research, and Scholarships, Los Angeles, CA, 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>

Santosh Singh Rathore · Sandeep Kumar

Fault Prediction Modeling for the Prediction of Number of Software Faults

Santosh Singh Rathore
Department of Computer Science and
Engineering
ABV-Indian Institute of Information
Technology and Management Gwalior
Gwalior, Madhya Pradesh, India

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

ISSN 2191-5768 ISSN 2191-5776 (electronic)
SpringerBriefs in Computer Science
ISBN 978-981-13-7130-1 ISBN 978-981-13-7131-8 (eBook)
<https://doi.org/10.1007/978-981-13-7131-8>

Library of Congress Control Number: 2019934353

© The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2019

This work is subject to copyright. All rights are solely and exclusively licensed 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.

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

Preface

Software fault prediction (SFP) can be defined as a process of predicting the fault-proneness of the given software modules using some historic software fault data. For the given software, SFP predicts faulty modules via the use of various software metrics and the fault information collected from the software repositories. The main aim of SFP is to reduce the fault-finding efforts and to increase the quality of the software. To help the software testers and managers, SFP process attempts to provide useful hints by identifying the probable faulty code areas that require extensive testing or refactoring. The typical software fault prediction model is constructed by using some machine learning or statistical techniques and is used to predict software module being faulty or non-faulty. Another way to predict the fault-proneness of the software modules is by predicting number of faults in a module.

In this book, we focus on the prediction of number of faults in the software modules. First, we discuss the generalized process of the software fault prediction and classification of software faults. Next, we discuss various regression techniques and ensemble methods for the prediction of number of faults. Subsequently, we discuss the state-of-the-art literature focusing on the prediction of number of faults. Further, we evaluate different techniques and some ensemble methods for the prediction of number of faults.

This book is organized into six chapters. Chapter 1 introduces the concept of software fault prediction and prediction of the number of faults. The chapter also discusses various classification schemes of software faults and provides information about the contribution and organization of this book. Chapter 2 provides a description of different regression techniques used for the prediction of number of faults. In addition, the chapter also provides a description of the ensemble methods and summarized the state-of-the-art techniques used for the prediction of number of faults in software systems. Chapter 3 presents an experimental analysis of homogeneous ensemble methods for the prediction of number of faults including details of used software fault datasets and categorization of fault datasets into different groups. Chapter 4 presents an experimental study of linear rule-based ensemble

methods for the prediction of number of faults and discusses the results. Chapter 5 presents an experimental study of non-linear rule-based ensemble methods for the prediction of number of faults and discusses the results. Chapter 6 concludes this book.

Gwalior, India
Roorkee, India

Santosh Singh Rathore
Sandeep Kumar

Acknowledgements

First, I would like to extend my sincere gratitude to Almighty God. I would like to express my sincere thanks to my institute, ABV-Indian Institute of Information Technology and Management Gwalior, India, for providing me a healthy and conducive working environment. I would also like to extend my thanks to National Institute of Technology, Jalandhar for providing me all necessary supports. 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 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 grateful to the editor and the publication team of Springer for their constant cooperation in writing this 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 love, blessings, 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 Fault Prediction	1
1.2	Classification of Software Faults	3
1.3	Advantages of Software Fault Prediction	6
1.4	Organization of the Book	8
1.5	Summary	8
	References	9
2	Techniques Used for the Prediction of Number of Faults	11
2.1	Regression Techniques	12
2.1.1	Linear Regression	12
2.1.2	Logistic Regression	13
2.1.3	Ridge Regression	13
2.1.4	Polynomial Regression	13
2.1.5	Principal Component Regression	14
2.1.6	Poisson Regression	14
2.1.7	Negative Binomial Regression	15
2.1.8	Partial Least Square Regression	15
2.1.9	Ordinal Regression	16
2.1.10	Quasi-Poisson Regression	16
2.1.11	Lasso Regression	16
2.1.12	Support Vector Regression	17
2.2	Ensemble Methods for Regression	17
2.2.1	Homogeneous Ensemble Methods	18
2.2.2	Heterogeneous Ensemble Methods	20
2.3	State-of-Art of Regression and Ensemble Methods for the Prediction of Number of Faults	22
2.4	Performance Evaluation Measures	25
2.5	Summary	27
	References	27

3 Homogeneous Ensemble Methods for the Prediction of Number of Faults	31
3.1 Homogeneous Ensemble Methods	32
3.2 Evaluation of Homogeneous Ensemble Methods	32
3.2.1 Software Fault Datasets	32
3.2.2 Experimental Setup	33
3.2.3 Experimental Procedure	35
3.2.4 Tools and Techniques Used for Experiment	35
3.3 Results and Discussion	35
3.3.1 Results of Group-1 for MAE and MRE	39
3.3.2 Results of Group-2 for MAE and MRE	39
3.3.3 Results of Group-3 for MAE and MRE	40
3.3.4 Results of Group-4 for MAE and MRE	41
3.3.5 Results of Pred(0.30) for All Groups of Fault Datasets	41
3.4 Summary	44
References	45
4 Linear Rule Based Ensemble Methods for the Prediction of Number of Faults	47
4.1 Linear Rule Based Heterogeneous Ensemble Methods	47
4.2 Evaluation of Linear Rule Based Heterogeneous Ensemble Methods	48
4.2.1 Software Fault Datasets	48
4.2.2 Experimental Setup	48
4.2.3 Experimental Procedure	49
4.2.4 Tools and Techniques Used for Experiment	51
4.3 Results and Discussion	51
4.3.1 Results of Group-1 for MAE and MRE	51
4.3.2 Results of Group-2 for MAE and MRE	53
4.3.3 Results of Group-3 for MAE and MRE	53
4.3.4 Results of Group-4 for MAE and MRE	54
4.3.5 Results of Pred(0.30) for All Groups of Fault Datasets	54
4.4 Summary	56
References	57
5 Nonlinear Rule Based Ensemble Methods for the Prediction of Number of Faults	59
5.1 Nonlinear Rule Based Heterogeneous Ensemble Methods	59
5.2 Evaluation of Nonlinear Rule Based Heterogeneous Ensemble Methods	60
5.2.1 Software Fault Datasets	60
5.2.2 Experimental Setup	60

5.2.3	Experimental Procedure	61
5.2.4	Nonlinear Learning Technique	62
5.2.5	Tools and Techniques Used for Experiment.	63
5.3	Results and Discussion	64
5.3.1	Results of Group-1 for MAE and MRE.	64
5.3.2	Results of Group-2 for MAE and MRE.	65
5.3.3	Results of Group-3 for MAE and MRE.	66
5.3.4	Results of Group-4 for MAE and MRE.	66
5.3.5	Results of Pred(0.30) for All Groups of Fault Datasets.	67
5.4	Summary	69
	References	69
6	Conclusions	71
	Closing Remarks	75
	Index	77

About the Authors

Dr. Santosh Singh Rathore is currently working as an Assistant Professor at ABV-Indian Institute of Information Technology and Management (IIITM), Gwalior, India. Earlier, he has worked as an Assistant Professor at National Institute of Technology Jalandhar. He has received M.Tech. from the Indian Institute of Information Technology Design and Manufacturing (IIITDM) Jabalpur, India, and Ph.D. from the Indian Institute of Technology Roorkee, Roorkee, India. He has published research papers in various referred journals and national and international conferences. Also, he has published a book in the SpringerBrief in Computer Science. His research interests include software fault prediction, software quality assurance, empirical software engineering, object-oriented software development, object-oriented metrics, and application of soft computing in software engineering. Email: santosh.srathore@gmail.com.

Dr. Sandeep Kumar (SMIEEE'17) is currently working as an Associate Professor in the Department of Computer Science and Engineering at the Indian Institute of Technology (IIT) Roorkee, India. He has supervised three Ph.D. theses, about 40 master dissertations, about 15 undergraduate projects, and is currently supervising five Ph.D. students. He has published more than 60 research papers in international/national journals and conferences and has also written books/book-chapters with Springer (USA) and IGI Publications (USA). He has also filed two patents for his work done along with his students. Dr. Sandeep is the member of the 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 (Govt. of India), NSF/TCPP early adopter award-2014, 2015, ITS Travel Award 2011 and 2013, and others. He is a member of ACM and senior member of IEEE. His name has also been enlisted in major directories such as Marquis Whos Who, IBC, and others. His areas of interest include Semantic Web, Web Services, and Software Engineering. Email: sandeepkumargarg@gmail.com, sgargfec@iitr.ac.in