Springer Series in Reliability Engineering

Long Wang · Karthik Pattabiraman ·
Catello Di Martino · Arjun Athreya ·
Saurabh Bagchi *Editors*

System Dependability and Analytics

Approaching System Dependability from Data, System and Analytics Perspectives

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ISSN 1614-7839 ISSN 2196-999X (electronic)
Springer Series in Reliability Engineering
ISBN 978-3-031-02062-9 ISBN 978-3-031-02063-6 (eBook)
https://doi.org/10.1007/978-3-031-02063-6

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Introduction

The idea of this book was born at the end of 2019, when we celebrated Professor Ravishankar K. Iyer's 70-year-old birthday. Professor Ravishankar K. Iyer is George and Ann Fisher Distinguished Professor in the Department of Electrical and Computer Engineering at University of Illinois at Urbana-Champaign (UIUC), Urbana, Illinois, USA. He has been our Ph.D. or Postdoctoral Advisor, and importantly, a lifelong mentor to us.

Professor Iyer has made seminal contributions to multiple sub-areas within the area of computing system dependability spanning his over 40-year career. And inspiringly, he is continuing to make more path-defining contributions. Therefore, this book took shape as reviewing some of the most important technical achievements in **four dominant themes in dependability**, namely *software dependability*, *large-scale systems and data analytics*, *healthcare and cyber-physical systems*, and *dependability assessment*. Each section is both a look back and a look forward. The look back describes the important milestones, several from the authors of the chapters, as well as detours on the way to the milestones. The look forward defines important open challenges, which are both relevant and technically challenging, needing concerted efforts from the community. Hopefully, this book will serve as a "call to arms" to the community to pick up some of these problems and to solve them.

Fittingly, we have a section with personal reflections from colleagues who have known Prof. Iyer well. The fact that they happen to be towering researchers in their own right adds more weight to these reflections. These reflections offer a view rarely seen in public documents and will, we hope, serve to inspire a fresh generation of researchers in the field of dependability and beyond.

Each section begins with a chapter, written by one of us, introducing the rest of the chapters in that section, and providing a broad perspective on the theme profiled in that section. These introductory chapters can serve as a guidepost for the reader wishing to selectively navigate through the chapters in the book.

Topic of Dependable Computing Systems

Dependability has long been studied in computer science and engineering—our premier conference, **IEEE/IFIP Dependable Systems and Networks**, or **DSN**, had its start in 1970. The importance of this area is understandable since human safety and well-being have long depended on computing and engineered systems. Research on computer system dependability has led to innumerable successes in fields as varied as follows: *aviation and space* (NASA was one of the early organizations that emphasized dependable computing), *supercomputing clusters*, *banking and finance*, *electric power*, *transportation*, and *distributed computing clusters.* As dependability earned more successes, we ventured into the construction of more complex large systems such as cloud platforms, big autonomous IT infrastructures, and the Internet of Things (IoT).

This book is titled *System Dependability and Analytics* to emphasize its focus on system dependability, rather than only of its component pieces, as well as its intersection with data-driven analytics and machine learning. This latter aspect is becoming increasingly important at a rapid pace. The impetus is coming from large amounts of data being generated by our systems, which are being analyzed for understanding dependability weaknesses and for mitigating effects of dependability failures. The field is growing, and we expect many foundational as well as applied advances to come in the next few years. This book is an early attempt to chart that course, though doubtless, there is a good deal of speculation involved in our charting activity.

Staging of Dependability Topics

In the early stage of his research career, Prof. Iyer worked on analysis of dependability data and building of dependability models from the data. Subsequently, he worked on the design of dependability technologies and measurement of system dependability. In the recent decade or so, his research focus has moved onto analytics-driven approaches to dependability, including a prominent focus on dependability in genomics and autonomous transportation. Correspondingly, this book features the four sections that approximately cover these themes. It also makes sense that Prof. Iyer's dependability research started with modeling and measurement and then steered toward application to use cases, as the models and measurement techniques gained maturity. Thus, his career exemplifies the synergistic relationship that should ideally exist between theory and practice. In terms of the target systems for the dependability techniques, Ravi's work spans a long arc. Correspondingly, this book follows such an arc covering dependability of mainframes (early era) to that of supercomputers and software systems, to analytics of healthcare systems, and now to CPS and autonomous systems.

We start off with the theme of software dependability where we look at software that goes in small to large devices. Then, we move to the dependability of large-scale systems and the aspect of data analytics introduced above. Next, we delve into the impact of dependability on healthcare and cyber-physical systems (CPS), two relatively recent but already highly impactful sub-areas. We then come to the topic of how to assess if our dependability design meets its goals or not. We end the book with personal reflections on Ravi from three of his colleagues at the University of Illinois at Urbana-Champaign.

Goals

By reading this book, the reader will obtain an understanding of leading-edge dependability techniques in the diverse areas of software, large-scale systems and data analytics, healthcare and CPS, and dependability assessment techniques. These are grouped into four corresponding sections of the book. The book does not aim for completeness of the coverage of these topics. Rather, it provides influential techniques that have strong theoretical foundations and, in many cases, have proven to be of practical value in real-world systems.

The contributors of this book are active researchers and practitioners in leading universities and research laboratories. They conduct research and build real-world systems, services, and technologies in the areas covered in this book. In the book, they bring forward their deep insights and provide their contemporary views and visions on dependability. Thus, researchers, professional practitioners, and graduate students will all obtain a clear-eyed view of the state of the art of the research and real-world practice of system dependability and analytics.

Biographical Note on Prof. Ravishankar K. Iyer

Professor Ravishankar K. Iyer is ACM Fellow, IEEE Fellow, AAAS Fellow, and served as Interim Vice Chancellor of UIUC for research during 2008–2011. He has received several awards, including the IEEE Emanuel R. Piore Award, and the 2011 ACM Outstanding Contributions award. He has supervised about 40 Ph.D. dissertations over his distinguished career.

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