

Computer Communications and Networks

Muthu Ramachandran  
Zaigham Mahmood *Editors*

# Software Engineering in the Era of Cloud Computing

 Springer


# Computer Communications and Networks

## Series Editors

Jacek Rak, Department of Computer Communications, Faculty of Electronics, Telecommunications and Informatics, Gdansk University of Technology, Gdansk, Poland

A. J. Sammes, Cyber Security Centre, Faculty of Technology, De Montfort University, Leicester, UK

## Editorial Board

Burak Kantarci , School of Electrical Engineering and Computer Science, University of Ottawa, Ottawa, ON, Canada

Eiji Oki, Graduate School of Informatics, Kyoto University, Kyoto, Japan

Adrian Popescu, Department of Computer Science and Engineering, Blekinge Institute of Technology, Karlskrona, Sweden

Gangxiang Shen, School of Electronic and Information Engineering, Soochow University, Suzhou, China

The **Computer Communications and Networks** series is a range of textbooks, monographs and handbooks. It sets out to provide students, researchers, and non-specialists alike with a sure grounding in current knowledge, together with comprehensible access to the latest developments in computer communications and networking.

Emphasis is placed on clear and explanatory styles that support a tutorial approach, so that even the most complex of topics is presented in a lucid and intelligible manner.

More information about this series at <http://www.springer.com/series/4198>

Muthu Ramachandran · Zaigham Mahmood  
Editors

# Software Engineering in the Era of Cloud Computing

 Springer

*Editors*

Muthu Ramachandran  
School of Built Environment, Engineering,  
and Computing  
Leeds Beckett University  
Leeds, UK

Zaigham Mahmood  
Debasis Education  
Derby, UK

Northampton University  
Northampton, UK

Shijiazhuang Tiedao University  
Hebei, China

ISSN 1617-7975

ISSN 2197-8433 (electronic)

Computer Communications and Networks

ISBN 978-3-030-33623-3

ISBN 978-3-030-33624-0 (eBook)

<https://doi.org/10.1007/978-3-030-33624-0>

© Springer Nature Switzerland AG 2020

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, expressed 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 Switzerland AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

*To*

*My mother Guruvammal; my wife Vasuki;  
and my daughters Virupa and Uma*

—Muthu Ramachandran

*To*

*My sisters Khalida Khanam and Irfana  
Mahmood; and brothers Masood Zaigham,  
Tahir Mahmood and Zahid Mahmood*

—Zaigham Mahmood

# Foreword

Software engineering has played a major role in the design, development, and management of all software-intensive systems for more than fifty years. Currently, service-oriented systems technologies and application environments such as Cloud Computing, Internet of Things, Fog and Edge Computing, Smart Home, Smart Cities, and Big Data are seamlessly integrated with the emergence of advancements in communication technologies. Therefore, this is a crucial moment adopting established software engineering principles and practices to service-based applications. In addition, it is beneficial to forge data science advancement to repositories of software engineering data such as PROMISE and other publicly available bug and failure data, thus creating a new era of *Software Engineering Analytics*. In this context, one of the main aims of this book is on the application of systematic approaches to the design, development, and implementation of cloud-based complex software systems and services that will allow parallelism, fast processing, integrated cloud-IoT-big data services, and real-time connectivity.

This authoritative text/reference describes the state of the art in Software Engineering in the Era of Cloud Computing (also known as cloud software engineering). A particular focus is on integrated solutions, which take into account the requirements engineering and domain modelling for cloud computing-based applications, software design methods for scalability, as well as flexibility, sustainability, and operability for distributed and cloud environments. Additionally, this book provides a discussion on software engineering analytics (a new area of interest in software engineering), software engineering best practices, as well as approaches on cloud-based testing, and software process improvement as a service. In particular, this reference text provides the following:

- Discusses the latest developments, tools, technologies, and trends in software engineering methods and techniques in the era of cloud computing.
- Reviews the relevant theoretical frameworks, practical approaches, and methodologies for cloud software engineering.

- Examines the key components of cloud software engineering processes and methods, namely cloud requirements engineering, cloud software design, cloud software development, cloud software testing, cloud software engineering analytics, and cloud software process improvement.
- Presents detailed contributions from renowned experts in the field of software engineering for distributed computing.
- Offers guidance on best practices and suggests directions for further research in distributed computing.

This illuminating volume is ideal for researchers, lecturers, and students wishing to enhance their knowledge of technologies, methods, and frameworks relevant to cloud software engineering for distributed environments. Software engineers and project managers interested in adopting the latest approaches will also find this book helpful as a practical reference. There are 13 chapters in this book and are organized in three parts:

Part I is on Cloud Requirements Engineering and Domain Modelling dedicated to providing a framework for service requirements, domain modelling approaches, and approaches to software security engineering for cloud computing.

Part II is on Cloud Design and Software Engineering Analytics with Machine Learning Approaches that presents chapters on design approaches to the design and development of cloud services and approaches on software engineering analytics with cloud-based machine learning tools.

Part III is on Cloud Testing and Software Process Improvement as a Service dedicated to providing chapters on cloud test as a service paradigm, Software Process Improvement as a Service (SPIaaS), thus providing automated testing and metrics to software industries.

In the light of the significant and fast emerging challenges that software engineers and service-oriented computing specialists face today, the editors of this book have done an outstanding job in selecting the contents of this book. In this context, I am confident that this book will provide an appreciated contribution to both software engineering, service computing, and cloud computing communities. It has the potential to become one of the main reference points for the years to come.

October 2019

Prof. Rajkumar Buyya  
The University of Melbourne, Melbourne, Australia



# Preface

## Overview

Software engineering (SE) is the application of engineering principles and technological knowledge for the development of software applications in a systematic manner. There are numerous approaches to SE, however, with the emergence of newer technologies and development platforms, and with the ever-increasing demands from the consumers for more sophisticated software applications, software engineers are now better able to build software that is much more complex, distributed, and scalable than before. Whereas, the traditional methods to building software are still valid if the user requirements are clear and well understood, newer approaches such as rapid application development (RAD), prototyping, and service-oriented software engineering (SOSE) are becoming much more attractive for various reasons including that large-scale highly complex, scalable, and distributed applications can be reasonably rapidly developed, embedding the highly desirable characteristics of functional independence, reuse, and maintainability, etc.

With the emergence of service computing vision and the cloud computing paradigm, software engineering has now moved into a new era. Although these are two different paradigms, there is much synergy between them in the sense that whereas service computing covers the whole life cycle of software applications development and provision, the cloud vision helps with the delivery and deployment of software as, e.g. the Software-as-a-Service (SaaS) and Software-as-a-Platform (SaaS).

Software engineers can combine the service and cloud computing paradigms in a SE framework to resolve some of the SE challenges, e.g. to manage the runtime quality-of-service of loosely coupled applications components (called services). Although cloud paradigm has its share of challenges, e.g. with respect to confidentiality, integrity, and security due to its multi-tenant environment, these are being sorted out with the passing of time.

With this background, although the above technologies are well developed, there still is an urgent need for even better integrated solutions to software engineering

and provision, taking into account the consumer requirements of scalability at all levels, thorough flexibility and sustainability, around the clock availability, secure multi-tenancy, and operability for large-scale distributed computing applications, especially for business users. In this respect, the current text aims to extend the existing body of knowledge in the field of SE in the era of cloud computing.

This book aims to capture the state-of-the-art on the current advances in the said subject area. Majority of the contributions in this book focus on: requirements elicitation for software engineering, applications design, cloud testing, SE process improvement, and software provision. Thirty-three researchers and practitioners of international repute have presented latest research developments, methodologies, current trends, state-of-the-art reports, and suggestions for further understanding, development, and enhancement of subject area of cloud software engineering, especially for distributed computing environments.

## Objectives

The aim of this volume is to present and discuss the state-of-the-art in terms of methodologies, trends, and future directions for *Software Engineering in the Era of Cloud Computing* (also known as cloud software engineering). The objectives include:

- Capturing the state-of-the-art research and practice relating to cloud software engineering and software engineering analytics with the use of data science, machine learning, and relevant processes.
- Discussing developments, tools, technologies, and trends in the subject area of cloud software engineering and software engineering analytics.
- Analysing the relevant theoretical frameworks, practical approaches, and methodologies for cloud software engineering and software engineering analytics.
- In general, advancing the understanding of the emerging new methodologies relevant to cloud software engineering and software engineering analytics.

## Organization

There are 13 chapters in this book. These are organized into three parts, as follows:

- **Part I: Cloud Requirements Engineering and Domain Modelling.** This section has a focus on approaches, research, and practices towards requirements elicitation. There are six chapters in this part. The Chap. 1 on Requirements Engineering Framework for Service and Cloud Computing (REF-SCC) discusses the use of BPMN as a method of requirement engineering in cloud business operations. The chapter also presents the requirements engineering

framework for service and cloud computing (BPMN-REF-SCC). Chapter 2 presents an effective requirement engineering approach for cloud applications that examine different deployment approaches for cloud-based applications. Chapter 3 has a focus on approaches to requirements engineering for large-scale big data applications. The Chap. 4 discusses mechanisms for domain modelling and migrating from monoliths to cloud-based microservices using a large-scale banking industry case study. Chapter 5 probes further into cloud-enabled domain-based software development and the Chap. 6 in this section provides a systematic literature review of security challenges in software engineering for the cloud.

- **Part II: *Cloud Design and Software Engineering Analytics with Machine Learning Approaches*.** This part of this book comprises three chapters that focus on software design approaches with reference to cloud computing and software engineering analytics, which combine data science modelling and machine learning techniques. The Chap. 7 presents a novel software engineering framework for software defect management using machine learning techniques utilizing Microsoft Azure. The Chap. 8 illustrates an approach for sentiment analysis of twitter data; it uses machine learning techniques. The Chap. 9 contribution in this section suggests a framework for connection handlers to illustrate design pattern for recovery from connection crashes.
- **Part III: *Cloud Testing and Software Process Improvement as a Service*.** There are four chapters in this section that focus on Cloud Testing as a Service (CTaaS) and Software Process Improvement as a Service (SPIaaS). The Chap. 10 provides an analysis of approaches and techniques, considering a modern perspective on cloud testing ecosystems. The Chap. 11 contribution in this part addresses an approach Towards Green Software Testing in Agile and DevOps Using Cloud Virtualization for Environmental Protection. The Chap. 12 presents a novel technique for Machine Learning as a Service for Software Process Improvement (SPIaaS) which autonomically collects SPI data and performs analytics for process improvement. The Chap. 13 contribution of this book presents a set of methods on comparison of data mining techniques in the cloud for the software engineering perspective.

## Target Audiences

The current volume is a reference text aimed at supporting a number of potential audiences, including the following:

- *Cloud Software Engineers, Cloud Service Providers and Consumers, Software Engineers, and Project Managers* who wish to adopt the newer approaches to ensure the accurate and complete system specifications.

- *Students and lecturers* who have an interest in further enhancing the knowledge of technologies, mechanisms, and frameworks relevant to cloud software engineering.
- *Researchers* in this field who require up to date knowledge of the current practices, mechanisms, and frameworks relevant to cloud software engineering.

Leeds, UK  
Northampton, UK/Hebei, China

Muthu Ramachandran  
Zaigham Mahmood

# Acknowledgements

The editors acknowledge the help and support of the following colleagues during the review, development, and editing phases of this text:

- Dr. S. Parthasarathy, Thiagarajar College of Engineering, Tamil Nadu, India
- Dr. Pethuru Raj, IBM Cloud Center of Excellence, Bangalore, India
- Prof. Andrea Zisman, Open University
- Prof. Bashar Nuseibeh, Open University
- Prof. T. R. G. Nair, Rajarajeswari College of Engineering, India
- Prof. Zhengxu Zhao, Shijiazhuang Tiedao University, Hebei, China
- Dr. Alfredo Cuzzocrea, University of Trieste, Trieste, Italy
- Dr. Emre Erturk, Eastern Institute of Technology, New Zealand.

We would also like to thank the contributors to this book: all authors and co-authors, from academia as well as industry from around the world, who collectively submitted thirteen chapters. Without their efforts in developing quality contributions, conforming to the guidelines and meeting often the strict deadlines, this text would not have been possible.

Leeds, UK  
Northampton, UK/Hebei, China  
August 2019

Muthu Ramachandran  
Zaigham Mahmood

# Other Books by the Editors

## By Muthu Ramachandran

### **Strategic Engineering for Cloud Computing and Big Data Analytics**

This reference text demonstrates the use of a wide range of strategic engineering concepts, theories, and applied case studies to improve the safety, security, and sustainability of complex and large-scale engineering and computer systems. It first details the concepts of system design, life cycle, impact assessment, and security to show how these ideas can be brought to bear on the modelling, analysis, and design of information systems with a focused view on cloud computing systems and big data analytics. ISBN: 978-3-319-52490-0.

### **Requirements Engineering for Service and Cloud Computing**

This text aims to present and discuss the state-of-the-art in terms of methodologies, trends, and future directions for requirements engineering for the service and cloud computing paradigm. Majority of the contributions in this book focus on requirements elicitation; requirements specifications; requirements classification; and requirements validation and evaluation. ISBN: 978-3-319-51309-6.

### **Enterprise Security**

This reference text on Enterprise Security is a collection of selected best papers presented at the ES 2015 International workshop. Enterprise security an important area since all types of organizations require secure and robust environments, platforms and services to work with people, data, and computing applications. This book provides selected papers of the Second International Workshop on Enterprise Security held in Vancouver, Canada, 30 November–3 December 2016 in conjunction with CloudCom 2015. The 11 papers were selected from 24 submissions and provided comprehensive research into various areas of enterprise security such as protection of data, privacy and rights, data ownership, trust, unauthorized access and big data ownership, studies and analysis to reduce risks imposed by data leakage, hacking, and challenges of cloud forensics. ISBN: 978-3-319-54379-6.

## By Zaigham Mahmood

### **The Internet of Things in the Industrial Sector: Security and Device Connectivity, Smart Environments, and Industry 4.0**

This reference text has a focus on the development and deployment of the industrial Internet of things (IIoT) paradigm, discussing frameworks, methodologies, benefits, and inherent limitations of connected smart environments, as well as providing case studies of employing the IoT vision in the industrial domain. ISBN: 978-3-030-24891-8.

### **Security, Privacy, and Trust in the IoT Environment**

This book has a focus on security and privacy in the Internet of things environments. It also discusses the aspects of user trust with respect to device connectivity. Main topics covered include: principles, underlying technologies, security issues, mechanisms for trust and authentication as well as success indicators, performance metrics, and future directions. ISBN: 978-3-030-18074-4.

### **Guide to Ambient Intelligence in the IoT Environment: Principles, Technologies, and Applications**

This reference text discusses the Aml element of the IoT paradigm and reviews the current developments, underlying technologies, and case scenarios relating to Aml-based IoT environments. This book presents cutting-edge research, frameworks, and methodologies on device connectivity, communication protocols, and other aspects relating to the Aml-IoT vision. ISBN: 978-3-030-04172-4.

### **Fog Computing: Concepts, Frameworks, and Technologies**

This reference text describes the state-of-the-art of Fog and Edge computing with a particular focus on development approaches, architectural mechanisms, related technologies, and measurement metrics for building smart adaptable environments. The coverage also includes topics such as device connectivity, security, interoperability, and communication methods. ISBN: 978-3-319-94889-8.

### **Smart Cities: Development and Governance Frameworks**

This text/reference investigates the state-of-the-art in approaches to building, monitoring, managing, and governing smart city environments. A particular focus is placed on the distributed computing environments within the infrastructure of smart cities and smarter living, including issues of device connectivity, communication, security, and interoperability. ISBN: 978-3-319-76668-3.

### **Data Science and Big Data Computing: Frameworks and Methodologies**

This reference text has a focus on data science and provides practical guidance on big data analytics. Expert perspectives are provided by an authoritative collection of 36 researchers and practitioners, discussing latest developments and emerging trends; presenting frameworks and innovative methodologies; and suggesting best practices for efficient and effective data analytics. ISBN: 978-3-319-31859-2.

**Connected Environments for the Internet of Things: Challenges and Solutions**

This comprehensive reference presents a broad-ranging overview of device connectivity in distributed computing environments, supporting the vision of IoT. Expert perspectives are provided, covering issues of communication, security, privacy, interoperability, networking, access control, and authentication. Corporate analysis is also offered via several case studies. ISBN: 978-3-319-70102-8.

**Connectivity Frameworks for Smart Devices: The Internet of Things from a Distributed Computing Perspective**

This is an authoritative reference that focuses on the latest developments in the Internet of things. It presents state-of-the-art on the current advances in the connectivity of diverse devices; and focuses on the communication, security, privacy, access control, and authentication aspects of the device connectivity in distributed environments. ISBN: 978-3-319-33122-5.

**Cloud Computing: Methods and Practical Approaches**

The benefits associated with cloud computing are enormous; yet, the dynamic, virtualized, and multi-tenant nature of the cloud environment presents many challenges. To help tackle these, this volume provides illuminating viewpoints and case studies to present current research and best practices on approaches and technologies for the emerging cloud paradigm. ISBN: 978-1-4471-5106-7.

**Cloud Computing: Challenges, Limitations, and R&D Solutions**

This reference text reviews the challenging issues that present barriers to greater implementation of the cloud computing paradigm, together with the latest research into developing potential solutions. This book presents case studies, and analysis of the implications of the cloud paradigm, from a diverse selection of researchers and practitioners of international repute. ISBN: 978-3-319-10529-1.

**Continued Rise of the Cloud: Advances and Trends in Cloud Computing**

This reference volume presents the latest research and trends in cloud-related technologies, infrastructure, and architecture. Contributed by expert researchers and practitioners in the field, this book presents discussions on current advances and practical approaches including guidance and case studies on the provision of cloud-based services and frameworks. ISBN: 978-1-4471-6451-7.

**Software Engineering Frameworks for the Cloud Computing Paradigm**

This is an authoritative reference that presents the latest research on software development approaches suitable for distributed computing environments. Contributed by researchers and practitioners of international repute, this book offers practical guidance on enterprise-wide software deployment in the cloud environment. Case studies are also presented. ISBN: 978-1-4471-5030-5.

**Cloud Computing for Enterprise Architectures**

This reference text, aimed at system architects and business managers, examines the cloud paradigm from the perspective of enterprise architectures. It introduces fundamental concepts, discusses principles, and explores frameworks for the



adoption of cloud computing. This book explores the inherent challenges and presents future directions for further research. ISBN: 978-1-4471-2235-7.

### **Cloud Computing: Concepts, Technology, and Architecture**

This is a textbook (in English but also translated in Chinese and Korean) highly recommended for adoption for university-level courses in distributed computing. It offers a detailed explanation of cloud computing concepts, architectures, frameworks, models, mechanisms, and technologies—highly suitable for both newcomers and experts. ISBN: 978-0133387520.

### **Software Project Management for Distributed Computing: Life-Cycle Methods for Developing Scalable and Reliable Tools**

This unique volume explores cutting-edge management approaches to developing complex software that is efficient, scalable, sustainable, and suitable for distributed environments. Emphasis is on the use of the latest software technologies and frameworks for life-cycle methods, including design, implementation, and testing stages of software development. ISBN: 978-3-319-54324-6.

### **Requirements Engineering for Service and Cloud Computing**

This text aims to present and discuss the state-of-the-art in terms of methodologies, trends, and future directions for requirements engineering for the service and cloud computing paradigm. Majority of the contributions in this book focus on requirements elicitation; requirements specifications; requirements classification; and requirements validation and evaluation. ISBN: 978-3-319-51309-6.

### **User-Centric E-Government: Challenges and Opportunities**

This text presents a citizen-focused approach to the development and implementation of electronic government. The focus is twofold: discussion on challenges of service availability, e-service operability on diverse smart devices; as well as on opportunities for the provision of open, responsive and transparent functioning of world governments. ISBN: 978-3-319-59441-5.

### **Cloud Computing Technologies for Connected Government**

This text reports the latest research on electronic government for enhancing the transparency of public institutions. It covers a broad scope of topics including citizen empowerment, collaborative public services, communication through social media, cost benefits of the Cloud paradigm, electronic voting systems, identity management, and legal issues. ISBN: 978-1466-686298.

### **Human Factors in Software Development and Design**

This reference text brings together high-quality research on the influence and impact of ordinary people on the software industry. With the goal of improving the quality and usability of computer technologies, topics include global software development, multi-agent systems, public administration Platforms, socio-economic factors, and user-centric design. ISBN: 978-1466-664852.

**IT in the Public Sphere: Applications in Administration, Government, Politics, and Planning**

This reference text evaluates current research and best practices in the adoption of e-government technologies in developed and developing countries, enabling governments to keep in touch with citizens and corporations in modern societies. Topics covered include citizen participation, digital technologies, globalization, strategic management, and urban development. ISBN: 978-1466-647190.

**Emerging Mobile and Web 2.0 Technologies for Connected E-Government**

This reference highlights the emerging mobile and communication technologies, including social media, deployed by governments for use by citizens. It presents a reference source for researchers, practitioners, students, and managers interested in the application of recent technological innovations to develop an open, transparent and more effective e-government environment. ISBN: 978-1466-660823.

**E-Government Implementation and Practice in Developing Countries**

This volume presents research on current undertakings by developing countries towards the design, development, and implementation of e-government policies. It proposes frameworks and strategies for the benefits of project managers, government officials, researchers, and practitioners involved in the development and implementation of e-government planning. ISBN: 978-1466-640900.

**Developing E-Government Projects: Frameworks and Methodologies**

This text presents frameworks and methodologies for strategies for the design, implementation of e-government projects. It illustrates the best practices for successful adoption of e-government and thus becomes essential for policy makers, practitioners, and researchers for the successful deployment of e-government planning and projects. ISBN: 978-1466-642454.

# Contents

<b>Part I Cloud Requirements Engineering and Domain Modelling</b>	
<b>1 Requirements Engineering Framework for Service and Cloud Computing (REF-SCC)</b> . . . . .	3
Krishan Chand and Muthu Ramachandran	
<b>2 Toward an Effective Requirement Engineering Approach for Cloud Applications</b> . . . . .	29
Abdullah Abuhussein, Faisal Alsubaei and Sajjan Shiva	
<b>3 Requirements Engineering for Large-Scale Big Data Applications</b> . . . . .	51
Thalita Vergilio, Muthu Ramachandran and Duncan Mullier	
<b>4 Migrating from Monoliths to Cloud-Based Microservices: A Banking Industry Example</b> . . . . .	85
Alan Megargel, Venky Shankararaman and David K. Walker	
<b>5 Cloud-Enabled Domain-Based Software Development</b> . . . . .	109
Selma Suloglu, M. Cagri Kaya, Anil Cetinkaya, Alper Karamanlioglu and Ali H. Dogru	
<b>6 Security Challenges in Software Engineering for the Cloud: A Systematic Review</b> . . . . .	131
Mohamed Alloghani and Mohammed M. Alani	
<b>Part II Cloud Design and Software Engineering Analytics with Machine Learning Approaches</b>	
<b>7 Software Engineering Framework for Software Defect Management Using Machine Learning Techniques with Azure</b> . . . . .	155
Uma Subbiah, Muthu Ramachandran and Zaigham Mahmood	

- 8 Sentiment Analysis of Twitter Data Through Machine Learning Techniques . . . . . 185**  
Asdrúbal López-Chau, David Valle-Cruz  
and Rodrigo Sandoval-Almazán
  
- 9 Connection Handler: A Design Pattern for Recovery from Connection Crashes . . . . . 211**  
Naghmeh Ivaki, Nuno Laranjeiro, Fernando Barros and Filipe Araújo
  
- Part III Cloud Testing and Software Process Improvement as a Service**
  
- 10 A Modern Perspective on Cloud Testing Ecosystems . . . . . 255**  
V. Vijayaraghavan, Akanksha Rajendra Singh and Swati Sucharita
  
- 11 Towards Green Software Testing in Agile and DevOps Using Cloud Virtualization for Environmental Protection . . . . . 277**  
D. Jeya Mala and A. Pradeep Reynold
  
- 12 Machine Learning as a Service for Software Process Improvement . . . . . 299**  
Supun Dissanayake and Muthu Ramachandran
  
- 13 Comparison of Data Mining Techniques in the Cloud for Software Engineering . . . . . 327**  
Kokten Ulas Birant and Derya Birant
  
- Index . . . . . 351**

# About the Editors

**Dr. Muthu Ramachandran** is a Principal Lecturer in the School of Built Environment, Engineering, and Computing at Leeds Beckett University in the UK. Previously, he spent nearly eight years in industrial research (Philips Research Labs and Volantis Systems Ltd, Surrey, UK) where he worked on software architecture, reuse, and testing. His first career started as a research scientist where he worked on real-time systems development projects. Muthu is an author/editor of several books including: *Software Components: Guidelines and Applications* (Nova Publishers 2008) and *Software Security Engineering: Design and Applications* (Nova Publishers 2011). He has also widely authored and published 9 books, over 100 journal articles, over 50 book chapters, and over 200 conferences papers on various advanced topics in software engineering, software security, cloud computing, and education. Muthu has led numerous conferences as chair and as keynote speakers on global safety, security and sustainability, emerging services, IoT, big data, and software engineering. Muthu is a member of various professional organizations and computer societies, e.g. IEEE, ACM, BCS (as Fellow), and HEA (as Senior Fellow). He has also been an invited keynote speaker on several international conferences. Muthu's research projects have included all aspects of software engineering, SPI for SMEs (known as Prism model), emergency and disaster management systems, software components and architectures, good practice guidelines on software developments, software security engineering, and service and cloud computing. Projects details can be accessed at the following sites:

- <http://www.leedsbeckett.ac.uk/staff/dr-muthu-ramachandran/>
- <https://www.scopus.com/authid/detail.uri?authorId=8676632200>
- <https://scholar.google.co.uk/citations?user=KDXE-G8AAAAJ&hl=en>
- [https://www.amazon.co.uk/l/B001JP7SAK?\\_encoding=UTF8&redirectedFromKindleDbs=true&rfkd=1&shoppingPortalEnabled=true](https://www.amazon.co.uk/l/B001JP7SAK?_encoding=UTF8&redirectedFromKindleDbs=true&rfkd=1&shoppingPortalEnabled=true)
- <https://www.linkedin.com/in/muthuuk/?originalSubdomain=uk>
- <https://twitter.com/muthuuk>
- <https://github.com/Muthuuk>

Muthu can be reached at [m.ramachandran@leedsbeckett.ac.uk](mailto:m.ramachandran@leedsbeckett.ac.uk) and [se4cloud-computing@gmail.com](mailto:se4cloud-computing@gmail.com).

**Prof. Dr. Zaigham Mahmood** is a published author/editor of twenty-eight books on subjects including electronic government, cloud computing, data science, big data, fog computing, Internet of things, Internet of vehicles, industrial IoT, smart cities, ambient intelligence, project management, and software engineering, including: *Cloud Computing: Concepts, Technology & Architecture* which is also published in Korean and Chinese languages. Additionally, he is developing two new books to appear later in the year. He has also published more than 100 articles and book chapters and organized numerous conference tracks and workshops. Professor Mahmood is the Editor-in-Chief of *Journal of E-Government Studies and Best Practices* as well as Series Editor-in-Chief of the IGI book series on *E-Government and Digital Divide*. He is a Senior Technology Consultant at Debesis Education UK and Professor at the Shijiazhuang Tiedao University in Hebei, China. He further holds positions as Foreign Professor at NUST and IIU in Islamabad Pakistan. He has also served as a Reader (Associated Professor) at the University of Derby, UK, and Professor Extraordinaire at the North-West University, South Africa. Professor Mahmood is a certified cloud computing instructor and a regular speaker at international conferences devoted to cloud computing, distributed computing, and e-government. Professor Mahmood's book publications can be viewed at: <https://www.amazon.co.uk/Zaigham-Mahmood/e/B00B29OIK6>.

**Part I**  
**Cloud Requirements Engineering and**  
**Domain Modelling**

# Chapter 1

## Requirements Engineering Framework for Service and Cloud Computing (REF-SCC)



**Krishan Chand and Muthu Ramachandran**

**Abstract** Requirements engineering (RE) is the most difficult and important stage of any business process or project development. This research endeavors to find out the characteristics and aspects of requirements engineering enforced by cloud computing. Business Process Modeling Notation (BPMN) has made an impact in the respect to capture the process and to make the changes accordingly for improvement in business operations. This chapter defines how BPMN can be used as a method of requirements engineering in cloud business operations. Furthermore, this chapter presents the requirements engineering framework for service and cloud computing (BPMN-REF-SCC) and will also discuss the reference architecture for service and cloud computing. Finally, the research delivers a case of financial cloud business, which has developed 15 hypotheses for the validation and evaluation through simulation.

**Keywords** Cloud computing · Business process modeling (BPM) and Business Process Modeling Notation (BPMN) · Requirements engineering framework (REF) · Service and cloud computing (SCC)

### 1.1 Introduction

While dealing with the cloud computing, the main problem is no one knows where the data has been saved and who can access the data; hence, software processes become more complex which is directly impacting the requirements engineering processes. Traditional software providers were not worried about the issues such as monitoring, evaluating performance, scalability, customization, and other concerns,

---

K. Chand (✉) · M. Ramachandran  
School of Built Environment, Engineering, and Computing, Leeds Beckett University, Leeds  
LS6 3QS, UK  
e-mail: [K.Chand7596@Student.Leedsbeckett.ac.uk](mailto:K.Chand7596@Student.Leedsbeckett.ac.uk)

M. Ramachandran  
e-mail: [M.Ramachandran@leedsbeckett.ac.uk](mailto:M.Ramachandran@leedsbeckett.ac.uk)

© Springer Nature Switzerland AG 2020  
M. Ramachandran and Z. Mahmood (eds.), *Software Engineering in the Era  
of Cloud Computing*, Computer Communications and Networks,  
[https://doi.org/10.1007/978-3-030-33624-0\\_1](https://doi.org/10.1007/978-3-030-33624-0_1)



though cloud providers need to address these non-functional application concerns which are quite essential for the success of cloud computing services.

For many years, researchers have been working in the field of cloud computing and requirements engineering. Some of them have also worked on the software process improvement areas but not discussed any specific design or framework for cloud computing requirements engineering process. Software engineering in cloud environment includes some major challenges such as software composition, query-oriented vs application programming interface (API)-oriented programming, availability of source code, execution model, and application management. In the respect to take advantage and to make cloud computing more useful, these challenges need to be addressed in the different software engineering processes and methodologies [1].

Some of the researchers have already tried prevailing tools, languages, and other methodologies in the cloud computing environment while considering requirement engineering methodologies which are typically focused on the object-oriented outcomes and service-oriented tools. The main problem in the cloud computing is the lack of standard, which can help to encounter the main objectives which are wrapping a different characteristic of cloud computing [2].

According to the research of Todoran et al., approaches and methodologies have been proposed. However, there was no practical suggestion made on the elicitation process to utilize by the cloud providers. In addition, another research of Respschlaeger et al. illustrated a framework which includes the evaluation benchmarks for the adoption of the cloud services. Furthermore, a framework has been deliberated by Schrödl and Wind for the validation of the traditional requirements engineering process with regard to implementation in the cloud. It has been also concluded that none of the collective models is appropriate to justify the requirements engineering under the cloud environment [3–5].

One of the researches of Guha, cloud computing, is the most modernized buildup for the IT business. However, there are a lot of challenges in the software engineering of a cloud computing platform which are not been examined yet. Moreover, no recommended cloud computing platform has been introduced. Furthermore, the cloud provider should also include the stakeholders in each stage or cycle of the extended programming methodologies of cloud environment [6].

BPMN helps researchers to create ideas and provide a platform to do the best research and development. Moreover, best practices and graphical presentation make it easily understandable. BPMN has different sub-processes and stages, which identifies the problem to make the best possible changes to improve the performance of a business process. Therefore, the research will use the BPMN as the requirements engineering process to collect the requirements for service and cloud business. This chapter is a detailed explanation of how BPMN can be important in the process of requirements engineering method. It can be seen in the previous research that investing less time and money in the requirements engineering process leads to project or product failure. BPMN plays a big role at the time of incorporating requirement engineering process to save a project to be failed.

This chapter will explain the importance of BPMN as a requirements engineering method for service and cloud computing in this research. Section 1.2 details briefly about the business process modeling and also explains the processes and sub-processes of BPMN and how these processes can be used as requirements engineering method. Section 1.3 provides a detailed explanation of the BPMN requirements engineering life cycle for service and cloud computing. Section 1.4 shows how BPMN works with other entities of the organization for service and cloud computing. With the help of above all sections, Sect. 1.5 introduces a unique requirements engineering framework for service and cloud computing (REF-SCC). Section 1.6 details a reference architecture diagram for REF-SCC. Finally, Sect. 1.7 depicts a requirements engineering framework for service and cloud computing (BPMN-REF-SCC) through experimental validation of a real cloud application of a credit card.

### ***1.1.1 Business Process Modeling***

The aim and objectives of an organization are accomplished by carrying out business maneuvers in a precise way, and this specific way is known as business processes. Business processes can be identified to fulfill the customer need and as per the detailed activities carried out by an enterprise to produce a product. Business processes are the main components of an organization and have a direct impact on the business performance and quality of the product for the success of the organization. From management to improvement of the processes, so many methodologies have been introduced to address the multiple characteristics of business processes.

As per the definition given by the Harrington, “a business process consists of a group of logically related tasks that use the resources of an organization to provide defined results in support of the organization’s objectives” [7]. Resources of the organizations and the task-related are the key elements to achieving the business objective. Effective utilization of the resources and task structure is very significant for the time cost and the quality of the product and for the organization as well.

Business process modeling (BPM) is the process of collection of tools and methods to get an in-depth understanding of a business process to manage and improve the performance of an organization. Business process modeling is the activity of demonstrating the internal procedures of the business to find out the current situation in order to improve in the future. There are different graphical models available for the business process management like flowcharts and Unified Modeling Language (UML) diagrams.

Due to its existence importance and descriptive nature of the process, the characteristics representation for the activities such as business process improvement, business process re-engineering and process standardization, business process modeling is the first stage to success the organizational targets or objectives [8].

The communication of ideas is very important for business and stakeholders. Numerous techniques are available for the communication purpose such as

documentary description and graphical representation. Graphical techniques used charts, diagrams, pictures, etc., for communication and exploration. As it is relating to pictorial art, it provides a spontaneous understanding of the ideas or concepts. The concept of addressing the problems related to business management operations in the graphic flora is known as business process modeling. Business process modeling helps the stakeholders and business operations to design and understand the business process and subsequently follow the analysis and improvement process until implementation [9].

Modeling and simulation are processes to reduce the complexity of the real-world business process. The main aim of the business process modeling and simulation is to review the complexity of a process directed to make it with fewer efforts, accordingly to ease the complexity of the business process and to make it simple and understanding. However, the main objective of the process modeler is to make the process understanding, to reduce the complexity in the practical world, and to design the complex models [10, 11].

Every single element or aspect of the business process needs to evaluate as these are used as a tool to control and advance the process. Numerous methods are used for the business process evaluation in the field of computer science. The main emphasis of computer science is to provide the support to carry out the business operations, database storage, computational methods and their other corresponding methods for graphical communications. Different stakeholders are involved in the organization in the numerous levels who evaluate the performance of the business process. According to the research of Lodhi, Koppen, and Sakke (2013), the different stakeholders and their involvement in the business process have been discussed. Executives provide the abstract-level evaluation such as profit and loss, and these figures are described in the graphical form and the textual descriptions. Managers are involved in the evaluation of low-level processes with more details of the business activities and the resources and also make some future projections [12].

Usually, the performance is evaluated in the quantifiable amounts which provide help to designate the quality of the process. Different techniques and methods are used for the business process evaluation and the processes, and its elements are evaluated in the aspect of time, cost, and quality. In the respect to get accurate and to get the real advantage of the evaluation process, it is necessary to involve all the participants of the organizations. In the evaluation process, it is important to have the full picture of the processes from the abstract level to a low level and it is also important to evaluate the overall impact of making any changes in the process.

### ***1.1.2 Traditional RE Method***

Requirements engineering includes the set of activities to discover, validate, elicit, analyze, document, and maintain the group of requirements for the desired process or system [13].

The main objective of requirements engineering is to discover the requirements of a business or product, which can provide quality and can be implemented into a

business effectively. Requirements engineering is a crucial task that can impact on the current business activities. Requirements engineering is used as the most powerful tool for gathering the requirements of a business process with due respect to analyzing and documenting the requirement of a process [14].

Figure 1.1 shows a landscape of requirements engineering (RE) techniques and process. The RE process consists of main elicitation, modeling, verification, and validation activities. This paper mainly focuses on modeling requirements with BPMN process diagrams which allows us to elicit, develop requirements models, and validate the models with BPMN simulations. Therefore, it forms an effective RE tool for eliciting cloud requirements and can also build UML design and generate services.

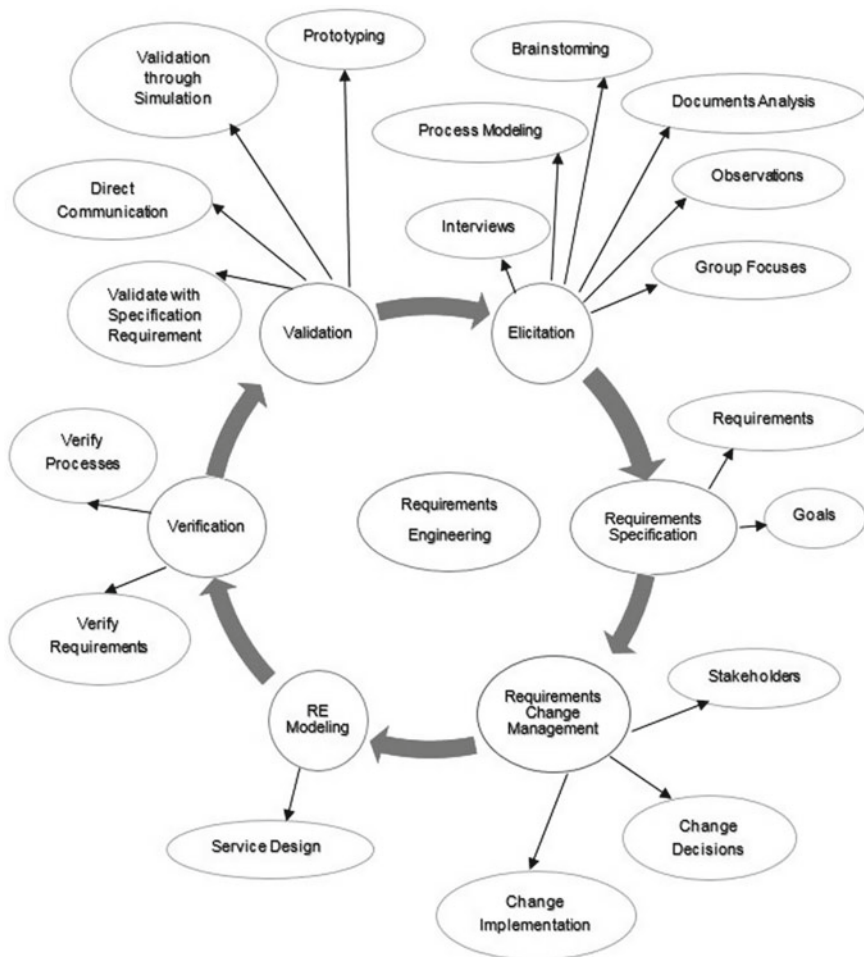


Fig. 1.1 Traditional RE method

The first and important process of RE is elicitation, which consists of sub-processes such as process modeling, document analyses, interviews, observations, and brainstorming. After that, requirements specification is the next process, where requirements need to specify according to business goals and requirements.

After specification of the business requirements, all the business stakeholders and managements decide if there are any changes required in current specified requirements. Modeling and verification are the next processes followed by validation process to complete the requirements engineering process. Validation is the final process, where direct meeting of all management and staff validates the process.

The next section describes the BPMN process, and its sub-processes and BPMN can be used as RE method.

## 1.2 BPMN as Requirements Engineering Method

This section is the detailed explanation of how BPMN can be important in the process of requirements engineering method. It can be seen in the previous research that investing less time and money in requirements engineering process leads to project or product failure. BPMN plays a big role here to save a project to be failed. This section will explain the importance of BPMN in this research.

Figure 1.2 shows the different process stages of the business process modeling technique. The process starts with the assessment to identify the problem, which leads the process to design and simulate and execution process to get the results and make improvement in current business operations. And the final task is to validate and test the process as the need to neglect an uncertain task. All these different processes will be explained in the next subsections.

### 1.2.1 Assessment

Figure 1.3 shows the first step of the business process to achieve the maximum of the current state of the business. Interviewing people working within the organization will provide the problems associated with the current process. While interviewing, the observation method can also help to investigate the loopholes. Additionally, another way is the feedback from customers can tell the story of problems with due respect to the customer.

- Interview people working within the organization to achieve the current state.
- Observation is the best way to find out the problems and to make the decision to resolve.
- Get feedback from the customers about their experiences.

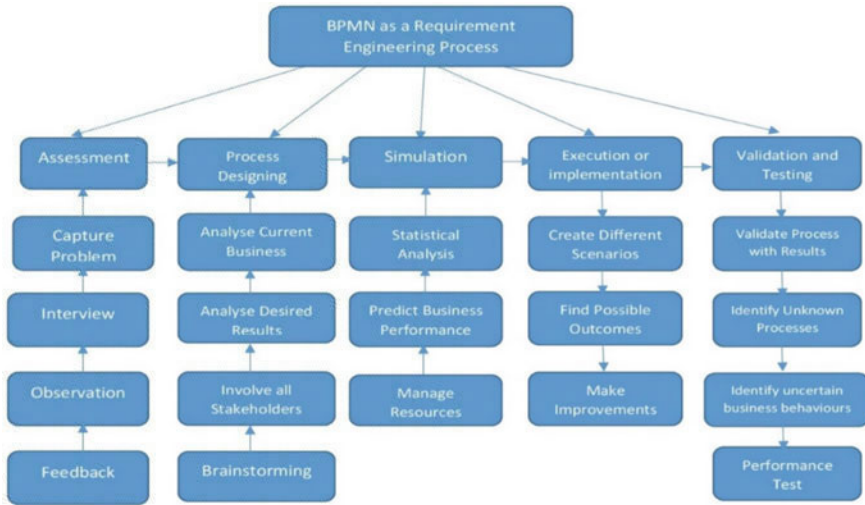
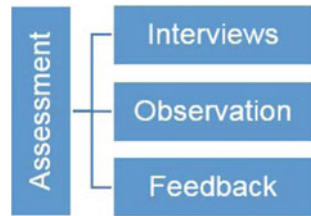


Fig. 1.2 BPMN as a requirements engineering method

Fig. 1.3 Business process assessment



### 1.2.2 Process Design

Figure 1.4 describes the next stage; once the process is captured and the problem is identified in the process, then the new business process can be developed or designed. Keep in mind the current business process, and affirm the changes in the process will get the desired results. Again, engaging all the major participants can help in considering the different ideas and suggestions for process improvement. Moreover, do not respite on one result, and brainstorming method can be used to get multiple solutions to consider the best.

- Investigate the existing problem in the process before designing and making changes.
- Evaluate the results of changes in the process.
- Involve all major participants to get the exact current state of the business.
- Do not rely on one solution, and brainstorming is the process to get a different solution to one problem.