

SPRINGER BRIEFS IN  
BUSINESS PROCESS MANAGEMENT

Ronny S. Mans  
Wil M.P. van der Aalst  
Rob J.B. Vanwersch

# Process Mining in Healthcare

Evaluating and Exploiting  
Operational Healthcare  
Processes



Springer

# **SpringerBriefs in Business Process Management**

**Series editor**

Jan vom Brocke, Vaduz, Liechtenstein

More information about this series at <http://www.springer.com/series/13170>

Ronny S. Mans · Wil M.P. van der Aalst  
Rob J.B. Vanwersch

# Process Mining in Healthcare

Evaluating and Exploiting Operational  
Healthcare Processes

Ronny S. Mans  
Eindhoven University of Technology  
Eindhoven  
The Netherlands

Rob J.B. Vanwersch  
Maastricht University Medical Center  
Maastricht  
The Netherlands

Wil M.P. van der Aalst  
Eindhoven University of Technology  
Eindhoven  
The Netherlands

ISSN 2197-9618 ISSN 2197-9626 (electronic)  
SpringerBriefs in Business Process Management  
ISBN 978-3-319-16070-2 ISBN 978-3-319-16071-9 (eBook)  
DOI 10.1007/978-3-319-16071-9

Library of Congress Control Number: 2015932849

Springer Cham Heidelberg New York Dordrecht London

© The Author(s) 2015

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.

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media  
([www.springer.com](http://www.springer.com))

# Acknowledgments

This research is supported by the Dutch Technology Foundation STW, Applied Science Division of NWO, and the Technology Program of the Ministry of Economic Affairs. The results were only possible due to the spectacular innovations in process mining over the last decade. Moreover, we heavily rely on powerful processes mining software (in particular ProM) that require major development efforts. We thank all “process mining enthusiasts” who contributed to the above.

# Contents

|          |   |    |
|----------|---|----|
| <b>1</b> | <b>Introduction</b>                             | 1  |
| 1.1      | Challenges in Healthcare                        | 2  |
| 1.2      | Process Mining: Data Science in Action          | 3  |
| 1.3      | Applying Process Mining to Healthcare Processes | 5  |
| 1.4      | Outlook   | 8  |
|          | References                                      | 10 |
| <b>2</b> | <b>Healthcare Processes</b>                     | 11 |
| 2.1      | Different Levels of Care                        | 11 |
| 2.2      | Classification of Healthcare Processes          | 12 |
| 2.3      | Four Types of Questions                         | 14 |
|          | References                                      | 15 |
| <b>3</b> | <b>Process Mining</b>                           | 17 |
| 3.1      | Event Data and Process Models                   | 18 |
| 3.2      | Three Types of Process Mining                   | 21 |
| 3.3      | The Process Mining Spectrum                     | 23 |
| 3.4      | Tool Support                                    | 24 |
|          | References                                      | 26 |
| <b>4</b> | <b>Healthcare Reference Model</b>               | 27 |
| 4.1      | Development Approach                            | 28 |
| 4.2      | The Model                                       | 29 |
| 4.2.1    | General Patient and Case Data                   | 30 |
| 4.2.2    | Process Steps                                   | 31 |
| 4.2.3    | Medication                                      | 36 |
| 4.2.4    | Patient Transport                               | 37 |
| 4.2.5    | Radiology                                       | 38 |
| 4.2.6    | Document Data                                   | 41 |

- 4.2.7 Organization and Buildings . . . . . 45
- 4.2.8 Nursing Plans . . . . . 47
- 4.2.9 Pathways . . . . . 48
- 4.3 Validation . . . . . 49
- References . . . . . 51
  
- 5 Applications of Process Mining . . . . . 53**
  - 5.1 Data Set from the Maastricht University Medical Center . . . . . 54
  - 5.2 Data Set from the Academic Medical Center . . . . . 57
  - 5.3 Process Mining Use Cases . . . . . 57
    - 5.3.1 Use Case 1: Exploring Selections of Events . . . . . 58
    - 5.3.2 Use Case 2: Identifying and Quantifying Deviations . . . . . 65
    - 5.3.3 Use Case 3: Identifying and Quantifying Bottlenecks . . . . . 67
    - 5.3.4 Use Case 4: Drilling Down . . . . . 70
    - 5.3.5 Use Case 5: Healthcare Process Comparison . . . . . 72
    - 5.3.6 Use Case 6: Context-Aware Process Mining . . . . . 75
    - 5.3.7 Outlook . . . . . 77
  - References . . . . . 78
  
- 6 Data Quality Issues . . . . . 79**
  - 6.1 Classification of Event Log Quality Issues . . . . . 80
  - 6.2 Evaluation of Data Quality Issues . . . . . 83
  - 6.3 Improving Data Quality: Guidelines of Logging . . . . . 86
  - 6.4 Garbage-In Garbage-Out . . . . . 88
  - References . . . . . 88
  
- 7 Epilogue . . . . . 89**



# About the Authors

**Ronny S. Mans** is a postdoctoral researcher at the Eindhoven University of Technology (TU/e). He is working in the Technology Foundation STW project “Developing Tools for Understanding Healthcare Processes” in which he focuses on the development of process mining techniques. He has published 10 journal papers, 30 refereed conference/workshop publications, and 8 book chapters. Ronny is a member of the editorial board of the KR4HC/ProHealth workshop and of the editorial board of the International Journal of Privacy and Health Information Management.

**Wil M.P. van der Aalst** is a full professor of Information Systems at TU/e. He is also the Academic Supervisor of the International Laboratory of Process-Aware Information Systems of the National Research University, Higher School of Economics in Moscow. Moreover, since 2003 he has a part-time appointment at Queensland University of Technology (QUT). His research interests include workflow management, process mining, Petri nets, business process management, process modeling, and process analysis. Wil has published more than 160 journal papers, 17 books (as author or editor), 300 refereed conference/workshop publications, and 50 book chapters. Many of his papers are highly cited (he has an H-index of 113 according to Google Scholar) and his ideas have influenced researchers, software developers, and standardization committees working on process support. He is also a member of the Royal Netherlands Academy of Arts and Sciences (KNAW), the Royal Holland Society of Sciences and Humanities (Koninklijke Hollandsche Maatschappij der Wetenschappen), and the Academy of Europe (Academia Europaea).

**Rob J.B. Vanwersch** is a program manager at Maastricht University Medical Center. In addition, he is a doctoral candidate and guest-lecturer within the Information Systems Group of the Department of Industrial Engineering and Innovation Sciences at TU/e. His research focuses on developing methodological support for redesigning business processes in health care. Rob Vanwersch has published several peer-reviewed journal and conference papers, and he is also a member of the user committee of the Technology Foundation STW project “Developing tools for understanding healthcare processes.”