Daniel Lübke · Cesare Pautasso *Editors*

Empirical Studies on the Development of Executable Business Processes

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To my family and my friends. Without them none of this would be possible. I am very glad to be surrounded by people who are that nice and support me every day. Thank you!

– Daniel

To my Hope for the future

– Cesare

Foreword

Executable business processes. At first sight, the topic may sound trivial to some people used to model business processes on a regular basis, yet I feel it is not. Getting from a graphical model to software (or a configuration thereof) that is able to automatically orchestrate other software components, such as web services or generic web APIs, or to coordinate people performing different business activities, requires not only familiarity with the chosen modeling notation but also intimate knowledge of the target runtime environment and of the model's execution semantics. Let's be frank: while it is relatively easy to draw some form of understandable process model on paper, for example, using Business Process Model and Notation (BPMN), how many of us have the necessary knowledge and skills to also deploy that model on a given business process engine and to successfully run it at the first attempt? I don't. At least, not any longer.

I first got in touch with business process modeling and execution during my PhD in the early 2000s, where I worked as teaching assistant of a course on workgroup and workflow management systems at Politecnico di Milano. I adopted model- and process-driven paradigms in my research since, e.g., to enable end users to model own process logics or to specify complex crowdsourcing processes. I used them in the research papers written together with other PhD students and colleagues, collecting lots of comments and criticism from reviewers. As senior PC member and PC chair of the International Conference on Business Process Management (BPM), I then had the chance to look behind the curtain and to review (and criticize) myself the work of others—an activity that also allowed me to get to know and appreciate the editors of this volume. Both Cesare and Daniel are known for their sensibility toward well-designed business processes and concrete practices. No frills.

This concreteness is evident in this volume. In fact, it brings together contributions that all provide some form of empirical perspective on or evidence of state-of-the-art business process management challenges. The first part of the volume looks into architectural aspects and covers the implementation of process-driven applications and the analysis of how data flow logics are supported. The second part proposes a set of case studies and experiments on the suitability of process modeling notations for the collection of requirements and on the implementation of process

support in both manufacturing and services industries—two sectors with contrasting business process requirements, ranging from very fine grained and repetitive to coarse grained and case based. The third and last part concerns quality, quality in terms of engine performance and process model correctness. The volume is the result of the joint work of authors from all over the world, and evidence itself of the significance and widespread acknowledgment of the problem of correct process execution and the need for concrete and repeatable results.

As researchers, teachers, and practitioners, how many times have we seen process models containing gateway nodes testing conditions without any prior activity producing the necessary data for the evaluation of the condition? How many times have we seen models where it was impossible to understand who was supposed to execute a given activity, sometimes not even being able to tell whether the executor was a software or a human agent? And how many times was it evident that a given model, although formally correct, would not meet expected running times?

Well, this volume will not teach you how to model your business processes or how to do so better. For this, lots of other books already exist. This volume provides you with a reasoned snapshot of empirical evidence showing that your impressions are right and of actionable results that you may want to know to prevent your concerns from coming true. That is, this volume shows you what other people like you actually learned in their projects, case studies, and experiments and how they solved their problems, in practice.

I am confident that, as a reader, you will find in this volume both practical hints and research stimuli, just like I did, and that you will appreciate the thoughtful selection of content as well as the meticulous work by the contributing authors.

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January 2019

Preface

Thank you for your interest in the topic of empirical research in the domain of executable business processes! We want to take you on an interesting tour on how technologies in this domain can be applied in practice and what obstacles and benefits projects actually encounter and how they can overcome the former and achieve the latter.

Executable business processes are one of the success stories of model-driven engineering (MDE) at the intersection of software engineering (SE) and business process management (BPM). On the one hand, an executable model is formally and precisely defined so that a computer is able to interpret it and execute it. On the other hand, models are visualized so that humans can describe, document, and optimize business processes at a higher level of abstraction than with traditional textual programming languages. While these important research areas have been long separated from each other, this book is an attempt at cross-fertilization, driven by the understanding that business processes are the software running today's digital organizations and that achieving a precise representation of such processes so that they can be reliably executed requires to adopt rigorous software engineering practices.

With the rising importance of digitalization and fully end-to-end automated or at least software-supported business processes, we expect the interest in executable business processes to rise and software technology supporting business processes to become ever more important in organizations across all domains and all sizes.

While research into executable business processes has been ongoing for a few decades, as witnessed, for example, by the significant efforts put into applying process technology within service-oriented architectures, our focus in this book is on empirical research. We wanted to compile an up-to-date snapshot featuring empirical case studies in order to assess and give visibility to examples of practical impact of BPM within the industry.

To lay some groundwork before starting on this book, we realized that empirical studies were hard to compare and that researchers lacked in their design concerning the collection of metadata of the analyzed processes, since such metadata is lacking from plain process model collections. Therefore, our first step toward this book was

the development of a template that allows an easy overview of the business process models used in a publication and gives researchers a template for collecting general metadata. You will find this template used in every chapter of this book, where it adds value to the chapter. A description of the contents of this template and how it was derived can be found in Chap. 2 in this book.

In the second half of 2017, we advertised a call looking for chapters that investigate questions of interests to both academia (e.g., identifying challenges for which no solution exists, new insights into how existing approaches are really used) and industry (e.g., guidelines for using certain technologies, guidelines for modeling understandable executable processes).

Our open call was answered with proposals by many interested potential contributors, spanning across both industry and academia, out of which we selected based on their relevance and quality the chapters in the book you are currently reading.

As a result, the book collects valuable real-world experience on the development and practical usage of executable business processes in software architectures, e.g., model-driven solutions that are built with languages such as BPEL or BPMN for the support and automation of digital business processes. This experience was acquired within different application domains (e.g., healthcare, high-tech manufacturing, software development), and it covers most phases of the software engineering life cycle (from requirements analysis to testing). We are also grateful to our chapter authors for explicitly featuring insights and takeaway messages directed to practitioners as well as to researchers.

Hannover, Germany — Daniel Lübke
Lugano, Switzerland — Cesare Pautasso
January 2019

How to Read This Book

Besides the background chapters found in Part I, this book presents research results and industry experience on a variety of topics related with executable business processes. Part II is concerned with architectural implications: what do we need to think about when implementing executable business process solutions. In Part III, two case studies and one experiment are presented. The case studies deal with how to successfully implement executable business processes in different domains, while the experiment is concerned with analyzing the effect of complementing use cases with BPMN process models. The two chapters of Part IV are concerned with extra-functional quality attributes (i.e., performance benchmarking and testability) of the solutions implemented with executable BPM.

You can read and skip ahead and back the different chapters as you like. All chapters close with takeaways for both researchers and practitioners. Researchers can find open challenges and new ideas for their research, while practitioners can read how to apply in their projects the valuable insights shared by the authors.

Book Chapters Overview

Part I. Background

Chapter 1, **Empirical Research in Executable Process Models**. Perhaps one of the reasons BPM research concentrates on analytical modeling of business processes is that BPMN is standardized fully in this regard and modeling tools support the notation very well. In this book, we focus instead on empirical research in executable process models. This requires a complete and precise specification of process models, which graduate from "PowerPoint slide" into an executable artifact running inside a workflow engine in the Cloud. In this chapter, we introduce fundamental background concepts defining executable business processes, discussing empirical research methods suitable for business process management, and presenting different architectural options for process execution and close with a brief history leading toward executable BPMN.

Chapter 2, **A Template for Categorizing Business Processes in Empirical Research**. Empirical research is becoming increasingly important for understanding the practical uses of and problems with business process technology in the field. However, no standardization on how to report observations and findings exists. This sometimes leads to research outcomes which report partial or incomplete data and makes published results of replicated studies on different data sets hard to compare. In order to help the research community improve reporting on business process models and collections and their characteristics, this chapter defines a modular template with the aim of reports' standardization, which could also facilitate the creation of shared business process repositories to foster further empirical research in the future. The template has been positively evaluated by representatives from both BPM research and industry. The survey feedback has been incorporated in the template. We have applied the template to describe a real-world executable WS-BPEL process collection, measured from a static and dynamic perspective.

Part II. Solution Architecture

Chapter 3, **Effectively and Efficiently Implementing Complex Business Processes: A Case Study**. The implementation of business processes has been neglected for many years in research. It seemed to be that only hard coding was the appropriate solution for business process implementations. As a consequence in classical literature about business process management (BPM), the focus was mainly on the management aspects of BPM, less on aspects regarding an effective and efficient implementation methodology. This has changed significantly since the advent of BPMN 2.0 (Business Process Model and Notation) in early 2011. BPMN is a graphical notation for modeling business processes in an easy to understand manner. Because the BPMN standard had the process execution in mind when it was designed, it allows for a new way of implementing business processes, on which the process-driven approach (PDA) is based. This approach has been applied in a huge project at SAP SE since 2015 comprising more than 200 business-critical processes. In order to get an impression about the power of the process-driven approach for really complex business process implementation scenarios, this chapter explains the basics about the process-driven approach and shares experiences made during the execution of the project.

Chapter 4, **Analysis of Data-Flow Complexity and Architectural Implications**. Service orchestrations are frequently used to assemble software components along business processes. Despite much research and empirical studies into the use of control flow structures of these specialized languages, like BPEL and BPMN2, no empirical evaluation of data flow structures and languages, like XPath, XSLT, and XQuery, has been made yet. This paper presents a case study on the use of data transformation languages in industry projects in different companies and across different domains, thereby showing that data flow is an important and complex property of such orchestrations. The results also show that proprietary extensions are used frequently and that the design favors the use of modules, which allows for reusing and testing code. This case study is a starting point for further research into the data flow dimension of service orchestrations and gives insights into practical problems that future standards and theories can rely on.

Part III. Case Studies and Experiments

Chapter 5, **Requirements Comprehension Using BPMN: An Empirical Study**. The Business Process Model and Notation (BPMN) has become the de facto standard for process modeling. Currently, BPMN models can be (1) analyzed or simulated using specialized tools, (2) executed using business process management systems (BPMSs), or (3) used for requirements elicitation. Although there are many studies comparing BPMN to other modeling techniques for analyzing and executing processes, there are few showing the suitability of BPMN models as a

source for requirements comprehension in projects where process-aware software is built without using BPMSs. This chapter presents a study aimed at comparing the comprehension of software requirements regarding a business process using either BPMN or traditional techniques, such as use cases. In our study, we analyzed responses of 120 undergraduate and graduate students regarding the requirements comprehension achieved when using only BPMN models, only use cases, or both. The results do not show significant impact of the artifacts on the comprehension level. However, when the understanding of the requirement involves sequence of activities, using the BPMN shows better results on the comprehension time.

Chapter 6, **Developing Process Execution Support for High-Tech Manufacturing Processes**. This chapter describes the development of an information system to control the execution of high-tech manufacturing processes from the business process level, based on executable process models. The development is described from process analysis to requirements elicitation to the definition of executable business process, for three pilot cases in our recent HORSE project. The HORSE project aims to develop technologies for smart factories, making end-to-end high-tech manufacturing processes, in which robots and humans collaborate, more flexible, more efficient, and more effective to produce small batches of customized products. This is done through the use of Internet of Things, Industry 4.0, collaborative robot technology, dynamic manufacturing process management, and flexible task allocation between robots and humans. The result is a manufacturing process management system (MPMS) that orchestrates the manufacturing process across work cells and production lines and operates based on executable business process models defined in BPMN.

Chapter 7, **Developing a Platform for Supporting Clinical Pathways**. Hospitals are facing high pressure to be profitable with decreasing funds in a stressed healthcare sector. This situation calls for methods to enable process management and intelligent methods in their daily work. However, traditional process intelligence systems work with logs of execution data that is generated by workflow engines controlling the execution of a process. But the nature of the treatment processes requires the doctors to work with a high freedom of action, rendering workflow engines unusable in this context. In this chapter, we describe a process intelligence approach to develop a platform for clinical pathways for hospitals without using workflow engines. Our approach is explained using a case in liver transplantation, but is generalizable on other clinical pathways as well.

Part IV. Quality

Chapter 8, **IT-Centric Process Automation: Study About the Performance of BPMN 2.0 Engines**. Workflow management systems (WfMSs) are broadly used in enterprise to design, deploy, execute, monitor, and analyze automated business processes. Current state-of-the-art WfMSs evolved into platforms delivering complex service-oriented applications that need to satisfy enterprise-grade performance

requirements. With the ever growing number of WfMSs that are available in the market, companies are called to choose which product is optimal for their requirements and business models. Factors that WfMSs' vendors use to differentiate their products are mainly related to functionality and integration with other systems and frameworks. They usually do not differentiate their systems in terms of performance in handling the workload they are subject to or in terms of hardware resource consumption. Recent trend saw WfMSs deployed on environments where performance in handling the workload really matters, because they are subject to handling millions of workflow instances per day, as does the efficiency in terms of resource consumption, e.g., if they are deployed in the Cloud. Benchmarking is an established practice to compare alternative products, which helps to drive the continuous improvement of technology by setting a clear target in measuring and assessing its performance. In particular for WfMSs, there is not yet a standard accepted benchmark, even if standard workflow modeling and execution languages such as BPMN 2.0 have recently appeared. In this chapter, we present the challenges of establishing the first standard benchmark for assessing and comparing the performance of WfMSs in a way that is compliant to the main requirements of a benchmark: portability, scalability, simplicity, vendor neutrality, repeatability, efficiency, representativeness, relevance, accessibility, and affordability. A possible solution is also discussed, together with a use case of micro-benchmarking of open-source production WfMSs. The use case demonstrates the relevance of benchmarking the performance of WfMSs by showing relevant differences in terms of performance and resource consumption among the benchmarked WfMSs.

Chapter 9, **Effectiveness of Combinatorial Test Design with Executable Business Processes**. Executable business processes contain complex business rules, control flow, and data transformations, which makes designing good tests difficult and, in current practice, requires extensive expert knowledge. In order to reduce the time and errors in manual test design, we investigated using automatic combinatorial test design (CTD) instead. CTD is a test selection method that aims at covering all interactions of a few input parameters. For this investigation, we integrated CTD algorithms with an existing framework that combines equivalence class partitioning with automatic BPELUnit test generation. Based on several industrial cases, we evaluated the effectiveness and efficiency of test suites selected via CTD algorithms against those selected by an expert and random tests. The experiments show that CTD tests are not more efficient than tests designed by experts, but that they are a sufficiently effective automatic alternative.

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Part III Case Studies and Experiments

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Part I
Introduction and Background

Chapter 1
Empirical Research in Executable Process Models

Daniel Lübke and Cesare Pautasso

Abstract Perhaps one of the reasons BPM research concentrates on analytical modeling of business processes is that BPMN is standardized fully in this regard and modeling tools support the notation very well. In this book, we focus instead on empirical research in executable process models. This requires a complete and precise specification of process models, which graduate from "PowerPoint slide" into an executable artifact running inside a workflow engine in the Cloud. In this chapter, we introduce fundamental background concepts defining executable business processes, discussing empirical research methods suitable for business process management, and presenting different architectural options for process execution and close with a brief history leading toward executable BPMN.

1.1 Executable Business Processes

Modeling executable business processes requires domain knowledge from business process management (BPM) combined with software engineering (SE) skills. Executable models are at the foundation of model-driven engineering (MDE), where running software systems are generated from formally specified, sufficiently detailed, and precisely defined representations of processes [14]. These specify the behavior of software compositions, both in terms of the control flow and data flow connecting different types of tasks, which when successfully executed together allows to achieve a given goal [20]. Is executable process modeling a refined form of visual programming? Or why are traditional developers skeptical when approaching

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