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Ingo M. Weber

Semantic Methods for Execution-level Business Modeling

Modeling Support
Through Process Verification
and Service Composition

Springer

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Foreword

Enterprises today act in an environment of continuously accelerating change. Since nearly all of an enterprise's activities are supported through IT, the adaptation of IT applications is necessary in a similarly quick fashion. Hereby Service-Oriented Architectures (SOA) and business processes play an important role, which thus have to be either re-designed or adapted accordingly.

This is where the work of Ingo Weber adds to the field, by creating new approaches for the development and adaptation of business processes, focused on an implementation-oriented point of view. Key questions are raised by the verification of specific properties of the processes as well as by the automatic composition of processes out of pre-defined components. The presented work hereby combines formal approaches with real evaluations in an impressive manner.

The work is structured in seven chapters, as follows. The introductory chapter puts forward the motivation for the study, the research questions, and an overview of the work and its central contributions. Subsequently, chap. 2 is concerned with the foundations of the work, where three areas are discussed: business process management, service-oriented computing, and semantic technologies.

Chapter 3 develops a detailed requirement analysis, presenting a total of 19 requirements. Since the breadth of the requirements is too large, the subsequently developed conceptual approach does not cover all of them. The developed approach distinguishes itself primarily by enriching process models with semantic annotations: this way, so-called annotated process models are created, which allow the specification of preconditions and postconditions. For the approach, a component-based architecture is introduced and complemented with a methodology giving targeted instructions on how to systematically use the offered components.

Chapter 4 introduces one of the central technical contributions of the presented work: the verification of annotated process models. Hereby, methods are developed which allow checking of the semantic annotations for consistency – in particular four verification tasks are addressed: (1) "effect conflict": are there activities which can be executed in parallel and whose postconditions are inconsistent; (2) "precondition conflict": are there parallel activities such that the postcondition of one is inconsistent with the precondition of the other; (3) "reachability": are there activities which are never reached in any process execution; (4) "executability": are there activities whose preconditions are not fulfilled albeit they are scheduled for execution; In a first step toward the solution, so-called annotated process graphs are formally defined in terms of syntax and execution semantics. Building on top of these definitions, the above-mentioned verification tasks are formalized, the computational complexity is analyzed, and algorithms for tractable cases of the above tasks are developed.

In chap. 5, new solutions for the composition of services are developed. Hereby, the typical trade-off between expressivity of the formalisms and the efficiency of the solution algorithms is taken into account. Substantial contributions of the developed approaches are according heuristics which make use of the domain knowledge presented in the ontologies, as well as methods for approximate reasoning. The developed solution approaches are first presented in an overview and then detailed step by step. Among others, the Web Service Composition problem is formalized for this purpose, and complexity results are introduced which depend on the expressivity of the formalisms for modeling domain knowledge.

Chapter 6 addresses the evaluation of the developed approaches. Five different prototypical scenarios are presented and illustrated with screen shots. In addition, empirical evaluations for the composition of services are discussed. The chapter ends with the presentation of evaluations based on several case studies.

The work concludes with a short summary and an outlook in chap. 7. Elaborate appendices include detailed proofs to the theorems formulated throughout the work.

The work presented by Ingo Weber contains original methodical contributions for the modeling and formal analysis of implementation-oriented process models. As such, the work impresses with the combination of strictly formally substantiated solution approaches and evaluations in practical application scenarios.

Karlsruhe, Germany
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Preface

The pace of change in the current economical world increases continuously. With respect to information technology (IT), there are currently two main trends with the goal of enabling organizations to adapt to changing circumstances On the one hand, software applications are being altered such that they offer Web services interfaces. This way, the business logic and the functionality become accessible from the outside in a standardized way. On the other hand, organizations increasingly apply methods from business process modeling. The vision is to create executable process models in very short time frames, which orchestrate the usage of Web services, and thus to enable the swift implementation of changed processes. However, the software tools offered today have difficulties to fulfill the demands that arise from the combination of the two technologies.

This monograph aims at the advancement of scientific knowledge on the implementation of business processes in organizations' IT systems. For this purpose, the monograph investigates if and how modelers of processes at the execution level can be supported using semantic technologies. Execution-level processes abstract from the technical details of Web services. Thus, they remain comprehensible for non-technicians. At the same time they reflect which Web services are available. We first analyze the requirements of process modeling support at this level. On this basis, we construct a conceptual framework supporting the majority of the requirements. For two of the components from the framework there were no sufficient solutions available. Therefore, we design detailed solutions for these: Firstly, we investigate the verification of annotated process models. As early as at design time, this type of verification can unveil conflicts arising from various sources such as an incorrect ordering of activities in a process model – e.g., when two activities are scheduled as parallel, but their parallel execution would lead to undefined results. Secondly, we investigate the problem of automatically composing semantically annotated Web services. This is relevant for finding an activity implementation made up of Web services. For both approaches we investigate trade-offs between expressivity and scalability, with an emphasis on scalability. Several prototypical

implementations enable the evaluation of the above components with respect to process models from practice.

The monograph was originally written as a PhD thesis with the Universität Karlsruhe (TH) while I worked at SAP Research in Karlsruhe, Germany. This environment allowed me to interact with many great researchers from academia, in particular from the AIFB institute, Universität Karlsruhe (TH), the IPE group at the Forschungszentrum Informatik (FZI), and several publicly funded projects, especially the EU-funded Integrated Project *SUPER*. People that were particularly influential in the creation of this monograph are: Anupriya Ankolekar, Sudhir Agarwal, Nenad Stojanovic, Tomasz Kaczmarek, James Scicluna, and Wil van der Aalst.

Special thanks go to my PhD supervisor Prof. Rudi Studer, who gave me the freedom to pursue my visions, yet guided me with insightful criticism and encouragement. I am also very grateful to Prof. Birgitta König-Ries, the second reviewer of my thesis, for her time and highly valuable feedback. Further I want to thank the other two members of my committee for their support, Prof. Andreas Oberweis and Prof. Christof Weinhardt.

My project leader, Christian Brelage, as well as my managers at SAP, Orestis Terzidis and Elmar Dorner, were extremely supportive by giving me substantial freedom in my work and by allowing me to participate in many international conferences and workshops. My research visit to SAP Research in Brisbane in early 2008 was also very fruitful, allowing me to collaborate with Alistair Barros, Marek Kowalkiewicz, Uwe Kylau, and Julien Vayssière, as well as with Shazia Sadiq and Guido Governatori from the University of Queensland, and Jan Mendling, at the time with Queensland University of Technology.

Further influential feedback came from Michael Altenhofen, Daniel Oberle, Roger Kilian-Kehr, Wasim Sadiq, Matthias Born, Ivan Markovic, Christian Drumm, and many more colleagues and students at SAP Research and from SAP product development groups. Jörg Hoffmann deserves special mention; as co-author on many of my publications he showed me how to apply formal methods to applied problems, and worked with me on many of the topics presented in this monograph.

Finally, I would like to thank my family, friends, and my partner, Susanne, for their patience and endurance during this intense time. Without their support, it would not have been possible to complete this work.

Sydney, Australia
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