Multi-Disciplinary Engineering for Cyber-Physical Production Systems

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Editors

Multi-Disciplinary Engineering for Cyber-Physical Production Systems

Data Models and Software Solutions for Handling Complex Engineering Projects

Springer

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ISBN 978-3-319-56344-2 ISBN 978-3-319-56345-9 (eBook)
DOI 10.1007/978-3-319-56345-9

Library of Congress Control Number: 2017940637

Printed on acid-free paper

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

Foreword

Being university professor implies the attempt to provide young engineers with the required knowledge enabling them to successfully work within a field of science, in my case the field of mechanical engineering. This knowledge shall be sufficient to also cope with challenges that will come up in the next few years.

Following this line of thought, the professional life of mechanical engineers, and in my case, product engineers, has strongly changed during the last 20 years. Within the field of product engineering, the increasing capabilities of information processing have resulted in two main trends.

First, the new capabilities of information processing enable radically improved or even new engineering methodologies. Examples for improved methodologies are more detailed analysis methodologies based on finite element methods or improved simulation methodologies, now also applying improved physics simulations. Examples of new methodologies are the development of advanced creativity techniques, optimization-based problem solution strategies, for example, exploiting swarm intelligence or genetic algorithms, or even new product prototype realization methodologies, such as 3D printing.

Second, the product itself can become more intelligent and, thereby, provide advanced product features, such as advanced user interaction for product customization, or product-related services, such as self-maintenance or self-adaptation.

All these new methodologies and technologies are based on advanced application of information processing. Thus, information creation, management, and use are key results, and also challenges, in the professional life of an engineer. Thus, student capabilities shall be trained to apply these improved or new methodologies and technologies. In addition, students shall be enabled to adopt upcoming concepts, methods, and technologies in their work environment efficiently and successfully.

To make this challenge more complicated also in product engineering, engineers will not work in isolation. Product engineers work in collaborations, in changing groups of engineers, who together aim at solving an engineering problem. Product engineers have to share knowledge with/from different engineering disciplines to enable the appropriate use of this knowledge.

As foundation, mechanical engineering students need to acquire key capabilities for dealing with information creation, management, and use within multi-disciplinary engineering environments. Many of the required skills are discussed in the book at hand. Within this book, the multi-disciplinary nature of the life cycles of products, production systems, and production system technologies and components are considered. The implications of these life-cycle activities toward information processing are highlighted and knowledge is collected that has the potential to enable engineers in several disciplines, not only mechanical engineering students, to successfully cope with important daily challenges in their professional work also in the foreseeable future.

Thereby, this book discusses three main fields of interest. First, following the common sense in engineering information processing by models is regarded. Here, the focus is on modeling structures and behaviors of products and production systems covering their complete life cycles. Second, integrated information flows along the product- and production-system life cycles are discussed supporting informed decisions of engineers by exchanging the required information in the right quantity and quality independent of its source. Finally, the integration of information processes in physical objects is discussed, based on the idea of cyber-physical systems and their occurrence in production systems as cyber-physical production systems.

Altogether, the book at hand is a valid source of knowledge for all readers intending to raise their knowledge related to information-driven engineering in a multi-disciplinary environment, not only to my mechanical engineering students.

Magdeburg, Germany Karl-Heinrich Grote
December 2016

Preface

Industrial engineering is a multi-disciplinary endeavor that is moving toward an interdisciplinary and information-driven approach in all application areas, including the engineering of *Cyber-Physical Production Systems* (CPPS). Engineers from several disciplines have to develop engineering results cooperatively by exchanging engineering information describing technical systems from different viewpoints and on various levels of detail. Within this interdisciplinary and information-driven approach, models of different kinds and their interrelations become key assets that should be treated as first-class citizens in the engineering process. Consequently, model-driven approaches envision improving engineering quality and reducing engineering efforts.

There is a growing community of engineers involved in the development of model-driven engineering approaches for product and production systems engineering in Europe and beyond, such as the members of the *AutomationML* association, the IEEE technical committees *Factory Automation*, *Industrial Agents*, *Industrial Cyber Physical Systems*, and *Industrial Informatics.* An overall goal of the research of these communities is to present a holistic view on CPPS from different research domains that address in some parts different viewpoints on the same topic but seem to act in isolation from related research groups in other communities. Challenges of CPPS can only be tackled by a cooperation of the relevant research communities.

Therefore, we provide this book to bridge the gap between the three scientific communities of multi-disciplinary engineering of products, production systems, and informatics with a focus on model-based software and information engineering with examples that should be relevant and understandable for members from all communities involved. To the best of our knowledge, this is the first book to cover the topic of *Multi-Disciplinary Engineering for Cyber-Physical Production Systems*, which has gained importance with the *Industrie 4.0* initiative. More flexible production systems require stronger integration of the models, methods, and tools across several engineering disciplines to reach the goal of automating automation. A major outcome of the research was that the later life-cycle phases of complex technical systems, i.e., operation, become more and more important. Engineering and modeling has to map run-time behavior adequately in advance. Real-time data

analytics in manifold ways increase the capabilities and efficiency of CPPS. CPPS-based Product Service Systems open new business opportunities.

Wien, Austria
February 2017

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