Preface

The study of *Semantic Modeling and Interoperability in Product and Process Engineering* deals with an advanced engineering informatics technology in supporting product and process modeling, development, implementation, and management.

This book is a condensed technology handbook for advanced modeling and application of engineering knowledge in product development and process management in industry. Computer-aided tools have been widely used in design and manufacturing activities. However, it is clear that most of these tools are not capable of incorporating engineering semantics into their solutions. Consequently, it is a challenge for the industry to model and apply comprehensive engineering knowledge, constraints, procedures, and concurrent aspects of design and manufacturing in a systematic and sustainable manner. In the past decade, feature-based design and manufacturing applications have gained momentum in the Computer-Aided Design and Manufacturing (CAD/CAM) domains to represent and reuse some design and manufacturing patterns with effective applicability. However, the actual scope of feature application is still very limited.

The editing author of this book intends to expand the scope of feature technology to the more open approach of engineering semantic modeling, and to provide a framework of technological solutions for system integration and information-sharing. This book presents a set of researched methods that can consistently represent and uniformly manage engineering semantics in the ever-dynamic evolvement of modern enterprise. With a proposed common infrastructure of product and process modeling, the interoperability among different computer systems is addressed based on a fine-grain feature-based informatics approach. This book also features some insightful case studies that show promising application prospects at different product stages and in different areas of design and manufacturing. Academics, advanced engineering students, and practicing engineers will benefit from the methodology and techniques proposed in the book, which will serve as useful references, guidelines, and helpful tips for their teaching, research, and development, as well as provide real engineering innovation projects which will increase industrial competency in the field of engineering informatics.

The proposed unified feature scheme, based on the associative feature concept and an important expansion of the well-known feature-based design and manufacturing approach, offers a systematic framework of fine-grain semantic modeling methods for representation and application of engineering knowledge, constraints, and associated engineering procedures. This semantic modeling technology supports uniform, multi-faceted, and multi-level collaborative system engineering with heterogeneous computer-aided tools, such as CAD/CAM, Computer-Aided Engineering (CAE), and Enterprise Resource Planning (ERP) applications. The enabling mechanism, which is essential to enable the proposed technology of implementing associative features, is introduced in detail from concept to implementation, then expanded to real-world applications. Practical case studies are provided to readers with insightful application references that enable readers to use the proposed method with some tested templates.

Semantic Modeling and Interoperability in Product and Process Engineering provides a reference solution for the challenging engineering informatics field, aiming at the enhancement of sustainable knowledge representation, implementation, and reuse in an open and yet practically manageable way. It is the authors' goal that this book becomes a valuable reference for scholars, practitioners, and learners from both academia and the engineering field.

There are 11 chapters in this book. They are organized as follows.

"Introduction to Engineering Informatics" gives a general definition of engineering informatics and reviews the current applications of modern engineering informatics in product development, concurrent and collaborative engineering, and chemical process engineering. A few fundamental technologies for developing engineering informatics solutions are briefly reviewed, including object-oriented software engineering, Unified Modeling Language (UML), multi-faceted data repositories, data mining, and semantic modeling. This chapter describes the context of engineering informatics which is the core theme of this book.

"A Review of Data Representation of Product and Process Models" reviews the state of the art in product and process informatics modeling and implementation. Through a systematic review, it concludes that interoperability among computer systems is a major hurdle. Feature technology is particularly reviewed for its strong versatility in engineering informatics. In this chapter, a special section is devoted to reviewing chemical process engineering informatics modeling systems and processes because this application domain has a unique nature which is different from other typical consumer product engineering practices, and has special local industrial relevance to the authors.

"An Example of Feature Modeling Application: Smart Design for Well-Drilling Systems" provides a typical feature modeling and implementation example, i.e., the development of an oil well drilling design calculation and CAD model generation software tool. Detailed system design modules, such as drilling well casing design, drilling string design, and operation parameter optimization, are described, and case demonstrations for these modules are presented.

"Fundamental Concepts of Generic Features" introduces the concept of *generic feature*, which is a fundamental concept of a common feature class definition that enables representations of different domain features on top of the generic feature with built-in methods to define the most common properties, such as geometric references, attributes, and the related constraints. The geometric and non-geometric consistency-checking methods are also discussed with a multi-view definition approach. Further, a preliminary entire product model with an open framework to accommodate multiple engineering applications is presented; this is the *unified feature* modeling framework.

"Unified Feature Paradigm" is related to "Fundamental Concepts of Generic Features" in that it offers more details about the *unified feature* modeling framework. In this chapter, the modeling scheme, cellular model representation, knowledge-based reasoning, and association and change propagation are presented. Constraint modeling, defined in a broader sense than just geometric constraints, is also illustrated with the help of graph theory. The key mechanism for maintaining feature consistency, i.e., the multiple-view association method in the unified feature system, which enables engineers to access data pertaining to specific engineering domains from the generic feature, is described. A new feature paradigm to support engineering interoperability has been established by "Fundamental Concepts of Generic Features" and "Unified Feature Paradigm".

"Features and Interoperability of Computer Aided Engineering Systems" explores advanced feature-related technologies from the angle of application. It begins with the development of CAx systems and their customization, then reviews the inherent problem of interoperability. After discussing the pros and cons of the most common approach, i.e., STEP-based data exchange and system integration, this chapter explores feature-based solutions with a thorough review of the research field. It provides a well-organized and carefully categorized reference for readers. One section is dedicated to chemical process engineering as well, which can be appreciated for the identification of interoperability gaps. An integrated system architecture is proposed.

"Data Representation and Modeling for Process Planning" presents an insightful research effort in data structure modeling in the domain of computer-aided process planning, which covers manufacturing procedure design with tool and machine alternatives based on a dynamic manufacturing environment. Data search algorithms are suggested with the support of various engineering databases. The system described can generate feasible manufacturing process solutions and estimate cost and time efficiently. With rich data and cases from the real world, this chapter will be a valuable reference for developers and researchers in the field.

"Computation of Offset Curves Using a Distance Function: Addressing a Key Challenge in Cutting Tool Path Generation" illustrates an important aspect of engineering informatics, i.e., the algorithms needed to deal with complex path problems. One of the most commonly used algorithms is curve offsetting; this chapter reports on a recent development of a curve offsetting model with a distance function. The method is different from the traditional approximating methods based on interpolation in that it approximates the progenitor curve with bi-arcs and generates the exact offset curve with direct error control.

"Feature Transformation from Configuration of Open-Loop Mechanisms into Linkages with a Case Study" proposes a feature synthesis method for design manipulators based on a hybrid method of Artificial Neural Network (ANN) and optimization techniques. This approach is useful for solving reverse linkage dimension design problems, such as an excavator design for a predefined reaching envelope profile curve. In fact, the proposed solution to this problem presents a typical example of mapping from the product specification feature to the product configuration feature.

"Feature-Based Mechanism Design" is a continuation of typical mechanism design as shown in "Feature-Based Mechanism Design", but focuses on dimensional synthesis, embodiment, and CAD model generation with minimum designer intervention. Parametric feature-based modeling is successfully applied in mechanism embodiment design. In both "Feature Transformation from Configuration of Open-Loop Mechanisms into Linkages with a Case Study" and "Feature-Based Mechanism Design", features are effectively used for semantic knowledge representation, product modeling, design process interactions, and design intent evaluation. These two chapters demonstrate an advanced feature modeling and engineering approach to embed and evaluate design intent.

"A Smart Knowledge Capturing Method in Enhanced Generative Design Cycles" proposes a new method to capture and reuse engineering knowledge through CAD and CAE interactions by recording journal files and creating reusable source codes for generative CAD and CAE integration. The CAD/CAE feature information and data associations are modeled and implemented in a common data model, which makes data sharing easily attainable. It offers a design automation solution for those products with relatively predictable configurations and constraints.

This book provides a systematic engineering informatics modeling and application methodology that is based on original research carried out over the past two decades. The in-depth descriptions of the new feature paradigm as well as in-depth process planning and product assembly data modeling are the book's primary achievement. Readers will benefit from the systematic theory and the numerous application cases, and are given exposure to the effectiveness and usefulness of the proposed engineering informatics methodology.

The editing author would like to take this opportunity to express his appreciation to all the co-authors of the 11 chapters for their significant contributions to this book. Their excellent research efforts, insightful observations, and valuable commitment have made this book much more solid in theory and rich in case studies. Among them, the editing author would specially thank Professor Qingjin Peng, from University of Manitoba, who contributed "Data Representation and Modeling for Process Planning"; and Dr. C. K. Au, from University of Waikato, who contributed "Computation of Offset Curves Using a Distance Function: Addressing a Key Challenge in Cutting Tool Path Generation". These chapters are substantial contributions complementary to other chapters, and make this book more complete in coverage. The author would also like to extend his sincere thanks to Dr. Rachel Hertz Cobb for her professional editing and patient correction

of those numerous typo and grammatical errors; and Miss Katy Moore who diligently formatted the book as per the publisher's requirement in a very short period of time. Their great effort has been instrumental to the timely delivery of this book as planned, and the consistent quality as expected.

Edmonton, AB, Canada, 2012 Y.-S. Ma

Springer
http://www.springer.com/978-1-4471-5072-5

Semantic Modeling and Interoperability in Product and
Process Engineering
A Technology for Engineering Informatics
Ma, Y. (Ed.)
2013, XVIII, 389 p., Hardcover
ISBN: 978-1-4471-5072-5