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Collaborative Product Design and Manufacturing Methodologies and Applications

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Preface

During the past few decades, there have been major innovation and paradigm shifts in product development methodologies and strategies. The current R&D trend is towards the development of collaborative design and manufacturing systems. The research theme is in line with the growing demand for global cooperative design and outsourcing in product development to gain better competitive advantage. Using the collaborative systems, designers and manufacturers can participate in global design chains and collaborate with partners locally and overseas to pursue competitive advantages. Furthermore, collaborative systems allow designers to work closely with suppliers, manufacturing partners and customers across enterprises' firewalls to obtain valuable inputs for their design and manufacturing activities.

From the early 1990s, some major R&D works have been reported, including the CyberCut system by the University of California at Berkeley; the FIPER (Federated Intelligent Product EnviRonment) system (FIPER Project, www.fiperproject.com/fiperindex.htm) funded by NIST; the Web-DPR system by the Georgia Institute of Technology), *etc.* Commercial systems include SolidWorks eDrawing™, Autodesk Streamline™, Impactxoft IX Design™, Onespace™, SmarTeam™, PTC ProjectLink™ and Windchill™, UGS TeamCentre™, *etc.* However, the developed strategies, methodologies and solutions still fall short of the expectation of the practical needs. They have not been generally accepted due to the weaknesses and limitations in collaboration management, interactive capabilities, security of data, real-time and ease of collaboration, *etc.* Different culture, educational background, or design habit of people also make it difficult to organize optimal collaborative design and outsourcing activities. To address the issues and make collaborative engineering more realistic and applicable, more efforts are being made.

The aim of this book is to update the relevant and recent research and development in this field. In this book, thirteen original and innovative chapters have been included to address the major challenges of developing collaborative design and manufacturing systems and techniques, with scientific and rigorous foundations as well as application values. The covered topics include: collaborative methodologies and strategies between humans, and between systems and humans to facilitate collaborative design and manufacture; cooperation across domains for multi-disciplinary design and manufacture; distributed system and service architectures for collaborative design and manufacture; interoperability of collaborative systems; new feature- and assembly-based methodologies for facilitating collaborative design and manufacture; workflow and conflict resolution/management in collaborative design and manufacture; design process and design change management in collaborative development, *etc.*

This book can be used as reference for mechanical/manufacturing/computer engineering graduate students and researchers in the fields of concurrent engineering and collaborative engineering for the efficient utilization, deployment and development of collaborative product design and manufacturing.

During the development of this book, we have received invaluable input and support from the chapter authors. We are also grateful to the editors of Springer-Verlag for their patience and professionalism during the editing process.

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An Adaptable Service-based Framework for Distributed Product Realization

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In this chapter, we propose a service-based engineering framework to support distributed product realization. Adaptability is the key strength of this framework, which arises from an appropriate balance between the ease of use of the framework and the flexibility for reconfiguration. *Standardization of the interfaces* between services permits communication between diverse software agents and relieves users from having to handle routine operations, resulting in the ease of use of the framework. *Flexibility of the framework's configuration* allows users to rapidly reconfigure the framework to changing design processes, and reduces the burden of customization. The capabilities for this adaptable distributed product realization framework are developed based on the Open Engineering Systems paradigm. Various existing distributed frameworks are evaluated against the requirements and missing features are identified. Our efforts towards the development of such a framework – the eXtensible Distributed Product Realization (X-DPR) environment are discussed. X-DPR is flexible and applicable to general industrial product realization processes. It is used to integrate distributed, collaborative product realization activities over the Internet. We trace the development of the framework based on design requirements. Features of X-DPR are implemented to satisfy the requirements. X-DPR is compared to existing engineering frameworks based on the required features. The key words and phrases used in this chapter are defined below.

Agent – Software component that can be invoked remotely to perform tasks in a product realization process.

Client – A software component that requests services from remote agents.

Framework – A computational backbone that facilitates deployment and utilization of agents.

Open Engineering Systems – Systems of industrial products, services, and/or processes that are readily adaptable to changes in their environment which enable producers to remain competitive in a global marketplace through continuous improvement and indefinite growth of an existing technological base.

Service – An activity that an agent can perform based upon a client's request.

1.1 Introduction

1.1.1 Need for an Adaptable Framework

Competition, globalization, a decreasing half-life of information, and greater product complexity necessitate the effective utilization of distributed resources and the management of the derived information. A distributed product realization process consists of a philosophy, a systematic approach and implementation methods to organizing product development activities. This process must be able to incorporate information from all parts of the product lifecycle. It is intended to support collaborative, concurrent decision making by geographically dispersed engineers who have different goals, knowledge, experiences, tools and resources. Software frameworks that facilitate globally distributed design and manufacturing activities are becoming more and more important, and many universities and industries have developed specific frameworks to complete specific tasks. However, in these frameworks, there is often a trade-off between agility, flexibility and implementation/customization effort.

If an engineering framework is implemented as *middleware*, it may be flexible enough to be useful for various product realization processes, but requires a significant effort to particularize it for a specific process. Middleware tools free users from having to write their own routines to handle reliable data transfer between applications or from having to worry about complexities when multiple systems are integrated. However, users still must write codes to integrate application functionalities. Examples of middleware toolkits include OMG's CORBA (Common Object Request Broker Architecture) [1] and Microsoft's DCOM (Distributed Component Object Model) [2]. On the other hand, if an engineering framework is developed as *end-user software*, the user must only put forth minimal effort but, in general, these frameworks are inflexible and cannot be modified easily when new situations arise, such as, when the company's design processes change. In other words, middleware tools provide standardization of communication protocols and leave a lot of integration work to the users whereas engineering frameworks (end-user software) provide easier integration capabilities but are not flexible. Hence, *choosing between the flexibility and ease-of-use of engineering frameworks is one of the primary challenges*.

Using a simple example, we demonstrate why an adaptable engineering framework is necessary. Imagine an engineering designer developing a simulation program and wanting to deploy it to a network so that it is available remotely for other engineers. To do this, a designer needs to do the following:

1. Implement a message and data construct to convey specifications (input and output) and data to and from the simulation program,