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Integrated Computer-Aided Design in Automotive Development

Development Processes, Geometric Fundamentals, Methods of CAD, Knowledge-Based Engineering Data Management

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Introduction

Automotive development requires flexible and powerful tools. In the current, highly competitive market, the need to continually reduce development time and costs is driving the ongoing creation of strategies that can provide intelligent and functional links between the many parties involved in vehicle development, including project engineers, ergonomic specialists, safety and crash departments, designers, and many more. While a combination of virtual design and simulation methods with physical development and testing procedures represents the current state-of-the-art, the trend is moving towards integrated virtual development processes. Such processes focus on the product itself while also taking into account a wide variety of potential production and supplier interrelationships, as well as lifetime-relevant factors pertaining to customer use, support, service, and disposal.

In automotive development, computer-aided design (CAD) is used to perform the geometrical product definition, which provides the basis for three-dimensional virtual product models. The models are built by combining main assemblies, sub-assemblies, and individual components, which brings the virtual models close to the configurations of physical products. In this process, design tasks are carried out using parametric-associative techniques, which require the implementation of design-process-related guidelines and project-specific default procedural steps. The realization of parametric-associative model structures and interlinked geometry elements in turn improves the geometry representation by adding elements related to design check features, information relevant to digital mock-ups, or calculations and logical functionalities. The separation of geometry elements and geometry-defining parameters enables the integration of complex computation procedures, the creation of interfaces with design-external processes, and the direct embedding of macro-based automated routines into the design software. In this way, formerly separated working fields (e.g. calculation and simulation) are integrated into or connected to CAD models.

To enhance engineering capabilities in modern product development, intelligent solutions for the collection, storage, and distribution of product and process-oriented data and knowledge must be implemented. Powerful management concepts are necessary to manage the complex information flow, processes, and documents during the development or modification of products. Engineering data management (EDM), which organizes the data flow throughout the development processes and prevents data redundancy, represents an important component in the generation of complex product structures in the context of multi-firm and global collaborations.

The book offers a comprehensive overview of integrated CAD, with a focus on development processes in the automotive industry. This focus does not limit the application of the methods, strategies, and tools described here to a specific industry, but rather provides well-defined boundary conditions within which the topic can be effectively discussed. Nevertheless, the basic findings of this book can certainly be transferred to other industries in the area of mechanical or mechatronics product development.

One primary aim of the book is to introduce and discuss the entire process chain of product design, including the basic methods of geometry creation, the application of CAD, the integration of design and engineering, and finally the management of information related to both product and process. This comprehensive overview of the methods and tools of virtual product development will provide the reader valuable insight into the complex web of interactions and connections that characterize product development.

The following paragraphs provide brief summaries of the nine chapters included here:

Chapter 1, *Automotive Development Processes*, includes a retrospect of achievements in the automotive industry and highlights the very different factors that have influenced the development of cars over the past 120 years. The wide range of requirements for current and future cars is then elaborated, in order to clarify the current challenges facing automotive development. In addition, the stages in automobile development are explained through a detailed analysis of the different project phases, including a discussion on the integration of virtual product creation throughout the entire development chain.

Chapter 2, *Overview of Virtual Product Development*, first provides a summary of the various stages in the life cycle of mechanical products. The main terms, definitions, and methods of computer-aided product development are then introduced. This includes the historical development of CAD, simulation, and data management. In addition, some selected, representative development workflows in automotive engineering are presented and discussed, and the chapter then closes with a brief introduction to the concepts of collaborative product development.

Chapter 3, *Geometric Fundamentals*, introduces the reader to the mathematical and geometrical concepts which form the basis of a CAD system. It starts from scratch and leads the reader through the fields of curves, surfaces, freeform techniques, interpolation, approximation, and a range of other geometrical topics. In effect, this section might also be considered a manual for standard CAD concepts. However, rather than simply listing the methods and algorithms, this chapter actually explains the ideas behind these elements. A proper understanding of these ideas and properties can help engineers perform their jobs more effectively.

Chapter 4, *Modeling Techniques in CAD*, includes a detailed introduction of design methods within the CAD environment. Structures and strategies of wireframe, surface, and solid modeling are presented and discussed in terms of their application in collaborative product development processes. Beyond the application of primary CAD functionalities, this chapter uses specific examples from the automotive industry to present a variety of methods for the efficient creation of mechanical components and assemblies.

Chapter 5, *Knowledge-Based Design*, covers the use of template models, integrated calculation and simulation procedures, and automated routines to support product design. Knowledge-based design enables the collection, storage, and reuse of expert knowledge, as well as the subsequent integration of know-how into development processes. Using examples from component and assembly development, the chapter elaborates on the potential of enhanced parametric-associative design and knowledge-based engineering used in combination with simultaneously linked calculation procedures.

Chapter 6, *Engineering Data Management* (EDM), describes the fundamental principles of this approach, which involves the interdepartmental and interdisciplinary integration of data and workflows in automotive product development. Both complete EDM use cases and the basic functional modules of CAD and computer-aided engineering (CAE) are described in the context of process-oriented product life cycle management approaches. Finally, the chapter also presents the system-oriented view by describing EDM system architecture with integrated computer-aided applications and data management systems.

Chapter 7, *Knowledge Management in Product Development*, describes product knowledge as a basis for investigation, as well as the development of such knowledge across the product life cycle. The chapter introduces and discusses the fundamentals of knowledge, knowledge management, and knowledge transfer, as well as the principle related basic models and approaches. Thus, the chapter offers a summary of current scientific findings in the area of knowledge management that serves as background for further analysis.

Chapter 8, *Knowledge-Based Engineering Data Management*, describes an approach for using process-oriented knowledge management to identify and organize knowledge-intensive activities in relation to data management activities. Modern design processes involve a variety of tasks (e.g. geometry creation, simulation) and product-specific characteristics (e.g. functional layout, materials, process-relevant data (e.g. for production), product structure, configuration), all of which can be managed with knowledge-based methods. Comprehensive knowledge exchange in product development requires effective data management strategies, which can be applied within knowledge-based EDM.

Chapter 9, *Advanced Applications of CAD/EDM in the Automotive Industry*, offers a selection of concrete use cases in automotive development. One use case includes an application of knowledge-based EDM, which highlights the importance of the interaction of knowledge processes and data management throughout virtual product development. This use case also describes the integrated application of CAD, simulation, and management throughout the daily operations of development processes. Another use case describes the integration of CAD data management in automotive engineering, which is an essential topic in the area of EDM. Finally, a use case describing an approach of a parametric-associative concept model for initial vehicle development highlights the various working fields involved in automotive concept phases and introduces a model for geometrical and functional integration.

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