Chapter 1.20
Virtual Modeling and Prototyping in Collaborative Product Design

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INTRODUCTION

Computer-aided design/computer-aided engineering (CAD/CAE) tools are a valuable resource in today's product development process. Among other features, these tools enable collaborative development, reduce costs, and improve the efficiency of the development process (McGrath, 2004). Virtual and networked organizations should explore these computational tools to the utmost.

Among CAD/CAE tools, virtual modeling and rapid prototyping are very pertinent for virtual and networked organizations due to the large impact those tools can have here (Wright, 2001). Adequately used, virtual modeling allows collaborative development to its full extent, either among team members inside a company or between companies involved in the development of a specific product. It is necessary to emphasize that CAD/CAE tools, particularly those for simulation of virtual models (either process simulation or structural modeling), can be very dangerous when used as a black box; a sensible analysis of results is a prerequisite to prevent complications in later stages of the process.

This article starts by describing the main stages of product design and engineering. The concept of virtual modeling and a comparative overview to traditional product development methods are provided. The current rapid prototyping techniques and their advantages and disadvantages are described. Last, some of today's main applications for CSCW within the framework of product design methodologies are analyzed.

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PRODUCT DESIGN AND ENGINEERING

The development of any new part or product is a complex operation, as it varies from product to product (Ulrich & Eppinger, 2004). However, the basic methodology employed is common to (nearly) every project. The main stages of this procedure include:

a. Defining the qualitative and quantitative requirements that will comply with the user needs and any predefined technical and technological specifications.
b. Establishing the project goals, milestones, and deliverables, including a detailed timetable;
c. Selecting the team that will implement the project, promoting communication and a collaborative environment, typically including designers, engineers, and production managers, aside from marketing personnel.
d. Conceptualizing the part through brainstorming aesthetic concepts, functional issues, ergonomics, and cost aspects.
e. Hand-sketching components, parts, and assemblies, including projections, cross-sections, and perspectives.
f. Creating detailed 3D virtual models that can be used for the multiplicity of purposes described in detail in the next article, including interaction with clients.
g. Prototyping the product (e.g., through rapid prototyping) and producing a prototype mold that can be used to make the final validation for very small series or even for a single item, allowing minor adjustments before starting production. This will also be useful for market testing.
h. Commercializing the product, including marketing, advertisement, and distribution.

Although each of these stages is vital to product design and development, the present discussion focuses on stages 6 and 7, due to the significant advances made in these areas over the past couple of decades. These advances, coupled with the increasing availability of computational resources such as high-speed data exchange, now allow an entirely different approach to collaborative and networked product development, allowing a virtual organization to undertake and successfully implement projects they would have been unable to tackle only a few years ago.

VIRTUAL MODELING

Virtual modeling consists of representing a physical object on a virtual environment. The virtual model is in fact a digital description of the physical object (Baxter, 2006). Any object can be considered here, from a vase to an automobile to a human body part. Usually, the virtual model is created and later visualized on a computer through 3D rendering, or in specific cases, through 2D projections.

Some of the issues that arise when creating a virtual model include:

a. **Accuracy:** Ensuring that the model is an accurate representation of the physical object. Although in some parts, it may be relatively simple to ensure this feature, the market trends and the need for innovation keep pushing for more complex geometries, the use of organic shapes, and the application of various textures and patterns on the surface of the objects. In some cases, if working from an existing part (reengineering or upgrading it), the use of 3D scanning technology is required in order to guarantee that the physical object features are accurately captured in the model. Note that typically accuracy in current 3D scanning technology can be around ± 0.025mm.
b. **Resolution or level of detail:** This is usually only meaningful when discussing a model