RAPID DEVELOPMENT OF A VIRTUAL PROTOTYPING ENVIRONMENT USING CAD DATA

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Abstract The ability to rapidly prototype a proposed design is becoming a key contributor towards fulfilling the business requirements embodied in a short time-to-market, in cost-effective and high quality manufacturing. Recognizing the design and development process along the lines implied by the concept. Concurrent Engineering means that advanced information technologies must be taken advantage of. The integration of existing technologies in CAD modeling, design, analysis, simulation, networked cooperation, and virtual reality (VR) leads to a distributed desktop-environment which provides the basis to take the greatest advantage of the Virtual Prototyping technique. Some of the basic difficulties in the virtual prototyping process are the contrary requirements of the design and presentation applications concerning the representation of the product data. Usually, 3D CAD models are extremely detailed, containing all categories of chamfers, bore holes, small pockets or protrusions. Contrary to this, a VR data structure focuses on visualisation and real–time interaction aspects. They have to be less detailed, due to the restrictions of the visualisation hardware. Therefore this paper describes strategies for the preparation of CAD data and reduction of the model’s complexity. In the past several years, the development of powerful computing hardware led to an increasing number of sophisticated engineering applications.

Different steps for CAD for Virtual Prototyping models are described. Also different possibilities for the reduction of the complexity of different products have been discussed with examples. Finally the author’s experiences of virtual prototyping has been explained.

Keywords: Virtual Prototype, 3CAD, Concurrent Engineering,

INTRODUCTION

The use of physical prototypes is a widely adopted technique to verify the design and the functional behaviour of complex products. Especially in the automotive and aircraft industry physical prototypes, also called mock-ups, are built to check aesthetically details and overall appearance of a product, to confirm that product s are easy to assembly and disassemble or to prove the ergonomically design of cars and aircraft. In the development cycle of these products a huge series of different prototypes is produced. Normally these prototypes are made by hand in specialized departments, which makes this technique especially expensive and time–consuming. Consequently the industry tries to establish new processes which reduce both costs and production time.

In the past several years, the development of powerful computing hardware led to an increasing number of sophisticated engineering applications. Especially in the area mechanical systems design an immense progress in the development of modeling, analysis, and simulation software has been achieved. 3D CAD systems provide high level modeling operations in combination with kinematics, NC simulation or FEM analysis. Real-time analysis and simulation software of multi body. These developments led to a vision of a computer-based prototype. While the occurrence of a physical prototype represents a realistic first model of a part, a computer based prototype realizes the functional behaviour of the underlying product model by means of computer based simulations. Due to this reason the term Virtual Prototype has been formed. The definition of Virtual Prototype has been given as “ a computer based simulation of a prototype system or subsystem with a degree of functional realism that is comparable to that

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of a physical prototype" by Haug et al. (1993).

The Virtual Prototyping Process can be regarded as an important method to shorten the product development time and to reduce or eliminate the use of real physical mock-ups. The greatest advantage of this process can only be taken if a full integration in the whole engineering process is achieved (Kress, 1995). The realization goes along the lines implied by the concept, Concurrent Engineering, which can be regarded as a systematic approach to an integrated product development which embodies parallel work, cooperation and information sharing among designers, mechanical engineers, manufacturing engineers and project managers. Different steps for CAD for Virtual Prototyping models are described. Also different possibilities for the reduction of the complexity are discussed with examples. Finally the author's experiences of prototyping is explained.

VIRTUAL PROTOTYPING

The intuitive approach towards object manipulation opens new possibilities of prototyping based on CAD model models. It will be possible to take the data model of a product as a virtual prototype instead of a real object to model and analyze geometry, functionality and the manufacturing of designed products interactively. We call the resulting technology Virtual Prototyping. Thus, virtual prototyping is redesigning existing concurrent engineering strategies towards interaction between people, tools and, and product data. This overcomes the restrictions of existing product development tools and environments in which parallel product development technologies are mostly independent tools and environments, which parallel product development technologies, are mostly independent and unaware of each other.

The primary goal of virtual prototyping is to reduce the number of or to avoid the fabrication of physical prototyping, therefore shortening the product development time. Further goal to support product design and presentation by qualitative simulations and analysis, so that even designers and managers can talk about product function, manipulate and modify the data model directly.

The idea is based on the integration of computer-supported modeling, simulation and presentation of product (Fig.1). The product model is the central element, which integrates all information about the product, and links different phases of product development. CAD and other modeling systems provides basic data like geometry, material, color and functional features. Simulation makes information about the dynamic behaviour and other physical characteristics available for the presentation.

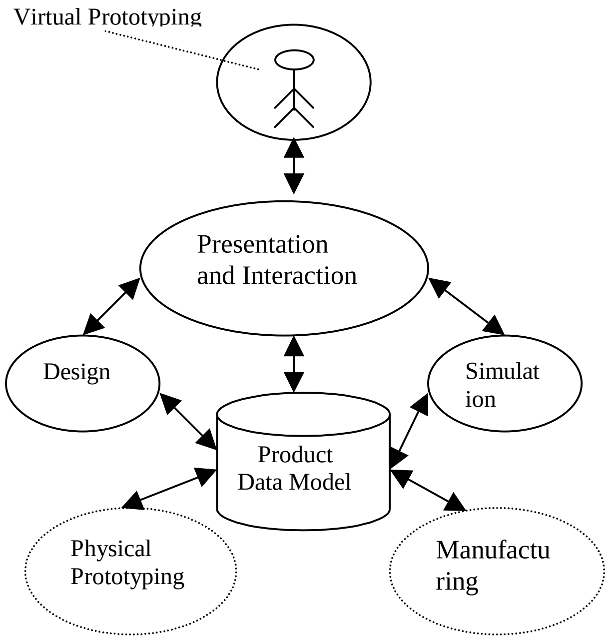

Fig. 1: Virtual Prototyping.

VIRTUAL PROTOTYPING USAGE

The improvement of the product development process is a major goal for companies and enterprises to remain competitive. Organization changes and the use of innovative software tools are inevitable to reduce product development time and costs. A key concept used to achieve this goal is concurrent Engineering. Focusing g on the design phase of a product, the notion of Concurrent Engineering has to be mapped on the requirements in this phase. Designers, Mechanical Engineers, and analysts have to be assigned to their work, as well as tasks and deadlines have to be communicated and checked. Hence a computer-based environment provides an optimized base for the execution of these tasks. The variety of the information handled in the design process and the complexity of the decision-making require graphical-interactive applications based on user-friendly concepts for the visualization of the information. Virtual Reality (VR) technology offers the possibilities to create such interactive environments. They are defined as real–time. Interactive graphics with three-dimensional models combined with a display technology that gives the user immersion in the model world and direct manipulation (Bishop et al.1992). This technology is especially suited for design activities, because of the interactive analyse-refine cycle. Any method which aids the designer during this process will improve the entire activity. Because a strength of VR is the capability for direct manipulation of objects within the virtual space, design activities should benefit greatly from this technology. A system incorporating real-time simulation of the functional behaviour, direct manipulations, and VR display technology realizes the interactive visualization of the virtual prototype. Several implementations have been realized in the area of the aircraft (Boeing) and automotive industry (Ford, Mercedes-Benz, BMW) etc.(Iqbal,M., 2000)

CAD DATA PREPARATION, CONVERSION AND ENRICHMENT AND REDUCTION OF THE COMPLEXITY OF THE CAD MODEL

3D geometry modeling CAD systems such as Auto CAD are widely used in engineering design. The main features of AutoCAD for geometry modeling are as follows:

- 3D interactive geometry modeling capacity.
- A layout of multiple views.
- A different 3D display mode (wireframe, removal of hidden lines, shaded images displays)
- Flexible user coordinate system.
- Graphics exchange interface.

AutoCAD is powerful for geometry modeling, like many other CAD system motion verification. Its capabilities are not integrated with the dynamic simulation capabilities discussed in above section. AutoCAD is very suitable as a graphics editor for geometric modeling especially for 3D geometric modeling. AutoCAD provides some primary 3D geometric modeling very easy. The geometric model of the mechanical system to be simulated is created by drawing each part of a mechanical system with respect to local coordinate system.

A series of operations has to be performed to convert CAD data to VR. Firstly, constant checking of the CAD model to ensure the geometrical representation. Gaps in joints, multi-patch surface, or multiple defined objects. CAD models contains numerous detailed objects like small bore holes, chamfers etc., E.g. for a clearance check of a virtual prototype these information are not relevant in this complexity and therefore be limited. This gives the opportunity to develop efficient virtual prototype. Fig. 2(a) and Fig. 2(b) shows conversion process of a 3D studio virtual model to an AutoCAD model and Conversion process of an AutoCAD model to a 3D Studio MAX Virtual model respectively (Iqbal, M., 2000).

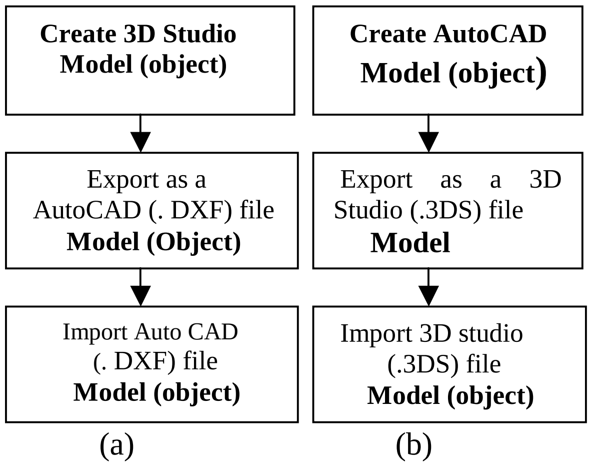

Fig.2 (a) Conversion process of a 3D studio virtual model to an AutoCAD model (b) Conversion process of an AutoCAD model to a 3D Studio MAX Virtual model.

Conversion of An AutoCAD Model to a Virtual Model in a Virtual Reality Software (Superscape VRT 5.5)

VRT includes a module that will import DXF files, in which solids that are created as drawing file are converted in VRT, to a series of facets. Fig. 3 illustrates the process of converting a realistic AutoCAD model into a Superscape VR model. 3-D Studio files can be used to change solids in the CAD application to surfaces as problems occurred when importing solids to VRT i.e. 3D Studio Max is a CAD application which may be used to convert solids into surfaces. The data converter module is mainly for converting data into three-dimensional VR formats. The conversion process involves a substantial amount of calculation and processing time, as the DXF file does not contain much of the specific information required by VRT i.e. DXF files were not created specially for importing blocks into VRT. Therefore the missing information is generated by the data converter which is often obtained by guesswork but can later be corrected by the user.

In most cases, however, a VRT data file bearing a close resemblance to a 3D representation of the original CAD model is produced.

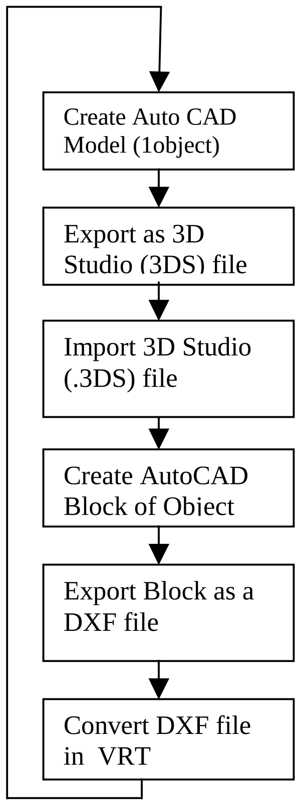

Fig. 3: Conversion process of a AutoCAD model to a Superscape virtual model.

The VRT converter is recommended for use on single object in order to obtain the best result i.e. each individual object should be run through the VRT converter.

Virtual Prototyping Environment

The framework for the realization of the virtual prototyping the principle concepts discussed above into a system architecture (Fig.4).

The virtual prototyping environment consists of the following VR-system components:

- VR interface
- Preparation unit
- Interaction unit
- Embedded tools
- VR data model and external tools
- Interface between the VR-system and the external tools, respectively.

In the future, the product data model base will contain the global, integrated product model data. CAD and simulation systems use special data formats, which must be converted into the data format of the VR system. BecauseCAD data do not support the specification of materials, texture and other information. (Muller et.al 1993).

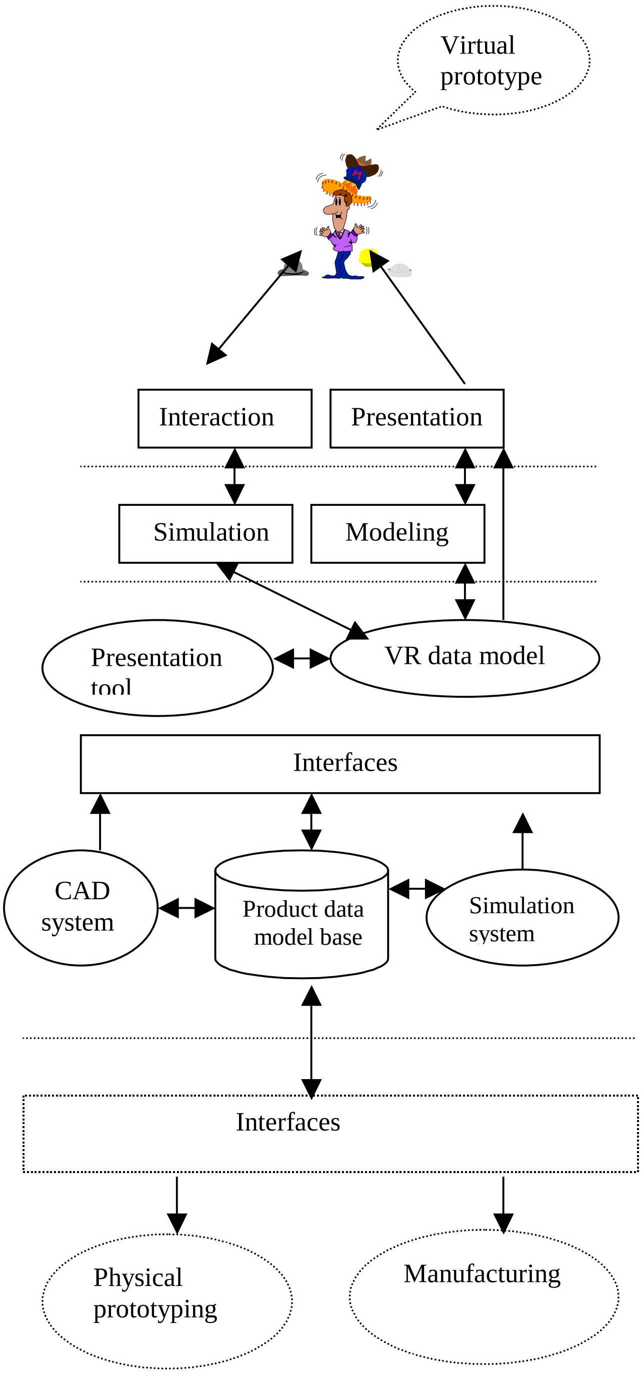

Fig.4: Virtual Prototyping Environment Architecture.

Integrated simulation tools provide information about product functionality on line and allow the virtual prototype to respond to a user's input. Modeling tools allow interactive changes of the virtual prototype.

The virtual prototyping environment consists of the following domains (fig.5)(ISO-CD 10303-22, 1993):

Product design:

This domain consists of several CAD-systems for the design of the product. These systems are either geometry.

<u>Simulation</u>

The simulation domain embraces applications for the physical simulation and also for the analysis of the product.

<u>Virtual reality</u>

The modeled products are put into the virtual reality domain to be presented in an advanced virtual environment. The virtual reality domain provides also he environment for the visualisation of physical simulations or analysis.

<u>Manufacturing process design</u>

The domain covers all applications for the computation of the manufacturing process. Here based on the designed and simulated product data, the data for the real manufacturing process are computed.

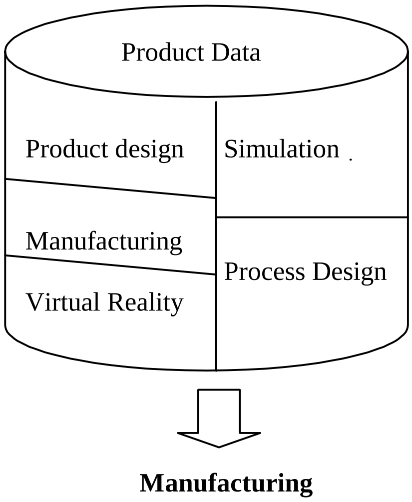

Fig.5 The Product Data Base and the Partial Models.

EXAMPLES OF VIRTUAL PROTOTYPING

Using CAD data and virtual prototyping combinely several application examples have been realized (fig.6). The Industrial Robot is used in manufacturing units in the automation of any modern manufacturing process. In a virtual environment, the motion of a robot can easily be understood. Maintenance training can be achieved virtually as shown in fig.6 before starting the real one (Iqbal, M., 2000). Fig.7 shows a virtual lathe developed for the educational purpose.

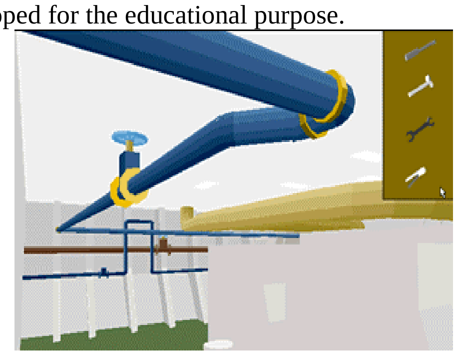

Fig.6 Virtual Maintenance Scenario.

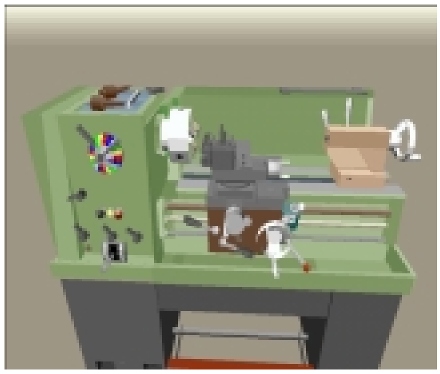

Fig.7 Virtual Lathe.

CONCLUSIONS

The application of virtual prototyping techniques contributes to a reduction in the time required to manufacture a prototype. It has a far-reaching strategic impact: Changing customer wishes can be reflected more quickly in product development, thus permitting companies to react more rapidly and therefore with greater agility to the requirements of the market. The availability of models and prototypes at an early stage results in a high level of product sophistication and greater availability of planning data for product. In the paper data preparation has been identified as one of the major constrain in virtual prototyping. Therefore fundamental problems of the CAD data preparation for virtual prototyping applications have been described. The paper surveys the concepts and application of the Virtual Prototyping process. Future development has to be towards a common data model for the Virtual Prototyping process and automatic conversion process for design application to achieve real time data exchange.

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