14

Towards a Virtual Prototyping Environment

U. Jasnoch, H. Kress, J. Rix
Fraunhofer Institute for Computer Graphics
Wilhelminenstr. 7
64283 Darmstadt, Germany
Tel. : +49 6151 155 (245 | 212 | 221)
Fax: +49 6151 155 299
Email : (jasnoch | kress | rix)@igd.fhg.de

Abstract

The paper will show and discuss the impacts and opportunities of a Virtual Prototyping Environment. The ability to rapidly prototype a proposed design in a Virtual Environment is becoming a key contributor towards fulfilling the business requirements embodied in a short time-to-market, in cost-effective and high quality manufacturing, and in easy support and maintenance. The major goal of the proposed Virtual Prototyping Environment is the integration of existing technologies in CAD modeling, Computer-Supported Cooperative Work, User Interface design, knowledge-based reasoning, process management and documentation, and virtual reality to offer a distributed desktop, computer-based environment to support the concurrent engineering method as it is applied to the product development process. The paper gives hints to the underlying product data model and the related organization in the data management system. In addition, it describes the first realized prototype and the resulting experiences.

Keywords

Virtual Prototyping, Software Environments, Product Model, CSCW

1 INTRODUCTION

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

J. Rix et al. (eds.), *Virtual Prototyping*

quality manufacturing, and in easy support and maintenance. Reorganizing the design and development process along the lines implied by the concept, *concurrent engineering*, means that advanced information technologies must be taken advantage of. However, most of today's generic, commercial, off-the-shelf technologies have to be extended and adapted to the needs of the product development process. In this context the term Virtual Prototype has been formed, defined by [HKF-93] as „a computer based simulation of a prototype system or subsystem with a degree of functional realism that is comparable to that of a physical prototype". A Virtual Prototyping Environment provides the basis to take the greatest advantage of this technique.

The major goal of the environment is the integration of existing technologies in CAD modeling, Computer Supported Cooperative Work (CSCW), User Interface (UI) design, knowledge-based reasoning, process management and documentation, and virtual reality to offer a distributed desktop, computer-based environment to support concurrent engineering as it is applied to the product development process. The product development process in virtual enterprises leads to virtual prototypes, which are no longer present at a single location. Instead, different parts and aspects of the prototype exist at the different locations of the virtual enterprise and may even change during the product development process.

The opportunities offered by Virtual Prototyping are several:

- to make use of the computer generated object in an electronic form for further communication, like sending it as a file over email or as an object in the distributed object-oriented data base, or using it in an electronic conferencing environment without requiring a physical model or hard-copy printouts.
- to overcome time differences and local distances by CSCW techniques like file transfer, email, object sharing, conferencing with multimedia communication integrated in the end-users desktop station, directly used in the end-users application environment.
- to allow direct cooperation within one application like cooperative editing, collaborative design, or expert sign-off. It would also allow shared "fly-through" with marketing or manufacturing personnel, top management, or key customers.

Another goal of the environment in the area of CAD is to provide new presentation techniques, incorporating multi-media audio and video techniques. In addition, new interaction techniques and user interfaces for 3D modeling and for interacting with the virtual prototype as presented in the virtual environment should be provided. The integration of new presentations of logical devices and new physical devices will be also necessary for manipulating the objects in the virtual prototype system.

This paper is organized as follows. The next chapter describes one basic aspect of a virtual environment, the underlying product model. Afterwards, the proposed environment will be described. A brief description of the first prototype is given in the following chapter. The paper ends with a conclusion.

2 THE UNDERLYING PRODUCT MODEL

Regarding the design and the manufacture of a product as a complex chain of different processes, continuous and homogeneous support by an environment will help to improve the product development process in the direction of enterprise integration based on an underlying product model. A product consists of other products and therefore represents an assembly of numerous different parts normally designed by different engineering groups using different applications. To be able to work together, applications must read, write and exchange their data in a well defined way, whereby each data item has to have a well defined unique meaning.

For a Virtual Prototyping Environment we propose to use an underlying, STEP-based product model according to the methodology developed by TC184/SC4 of the International Standardization Organization (ISO). STEP is an acronym for "Standard for the Exchange and the Representation of Product Model Data" and characterizes the emerging standard for the exchange of product model data [ISO-1]. By means of the STEP product data model and rules for the handling of these models it will be possible to describe product data in a unified way and to share product data between different systems without any loss of information. As STEP is not only focusing on implementations like physical file exchange [ISO-21], the conceptual model should be the basis for product database implementations or application programming interfaces. The STEP product model should whenever possible cover all properties by which a product is characterized during its life cycle. This requires the representation of all data, which are generated in the Virtual Prototyping System during all phases from design, construction, manufacturing, assembly, installation, quality control, utilization, maintenance to dismantling, destruction and recycling of a product. The information model ensures that data remain consistent during the different life cycle phases.

As in STEP, the Virtual Prototyping data management approach uses a product model concept, which is based on coherent partial models. Partial models are well defined subsets of concepts, which are combined based on some commonalties (e.g. geometry or product structure) as indicated in figure 1.

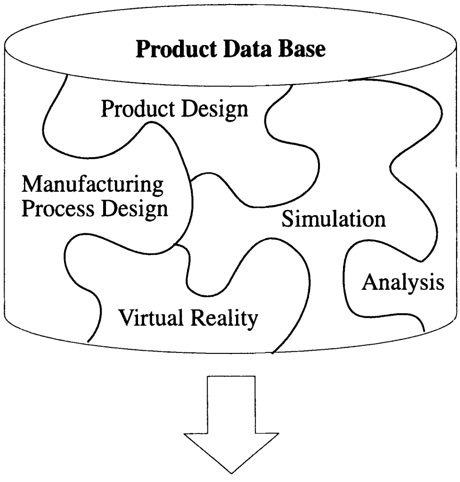

Figure 1: The Product Data Base and the Partial Models.

The integrated product models cover all aspects of the applications integrated in the Virtual Prototyping Environment. According to the models, the applications are grouped into domains. The underlying product data model consists of the following views:

- Product Design
  This view covers most of the aspects needed for CAD-Systems. It could deal with geometry-based data as well as with feature-based one. Here, the initial parts of the product are described.
- Simulation and Analysis
  The Simulation and Analysis view describes the additional data needed for the analysis domain, e.g. FEM-Analysis, and the simulation domain. In addition to the tested data, the results are stored, to provide the basis for comparing different versions of a product.
- Virtual Reality
  This view deals with all the additional aspects for the presentation of the product data, e.g. texturing information or light models.
- Manufacturing Process Design
  In addition to the simulation and analysis view, the view covers the aspects of the pre-manufacturing process. Based on the data of the other views, additional data for manufacturing, e.g. NC-data, is defined.

These different views and partial models constitute the whole product data base, covering most of the product relevant data. Based on this created, simulated, and presented data, the real manufacturing process of the product could start.

STEP defines not only the off-line data exchange, it also defines the methods and interfaces for the on-line data access [ISO-22]. The document describes two different kinds of access methods:

- the generic interface methods (in terms of implementation: late binding)
- and the specific interface methods (in terms of implementation: early binding).

Using these methods definitions is a basis for the transparent access to the product data model for integrated applications. It ensures the correct semantics and usage of the different data items and provides the possibility of a homogeneous data flow through the different applications.

Besides the schema point of view to the product data base, the object and methods point of view to the data base is also of importance. Figure 2 presents a partial view on the resulting

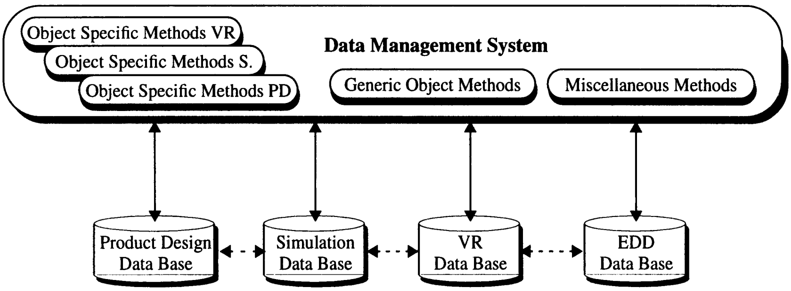

Figure 2: The Data Management System.

data management schema, where some of the schemas are skipped. Basically, this figure shows from the interface point of view that there exist globally usable miscellaneous methods, e.g. those for transaction management, generic object methods applicable for all objects, and schema and object specific methods directly attached to those objects. By providing such interfaces to the product data, uniform access and interchangeability is guaranteed. For logical and implementation reasons, the different views are separated into different data bases. By using a modern distributed object-oriented data base, the access to objects located in another data base is hidden and managed by the underlying data base. These relations are indicated by the dotted arrows.

One major benefit of using an object-oriented data base is the granularity of data access and locking. As the smallest available data item is an object, representing e.g. geometric data like a b-spline, the applications have the possibility to work and therefore lock only with the data which is really needed. Previously, a large amount of data was locked without taking care of the real data needed by the application. By providing this granularity with advanced locking and data management concepts, the parallel working is supported and the turn-around cycles are shortened. In addition, concepts as version and configuration management could be better supported based on the objects. These concepts are especially important in the early design phases.

3 THE ENVIRONMENT

To meet the goals, the Virtual Prototyping Environment consists of a framework and integrated applications, shown in figure 3. In this figure, only some of the existing application domains

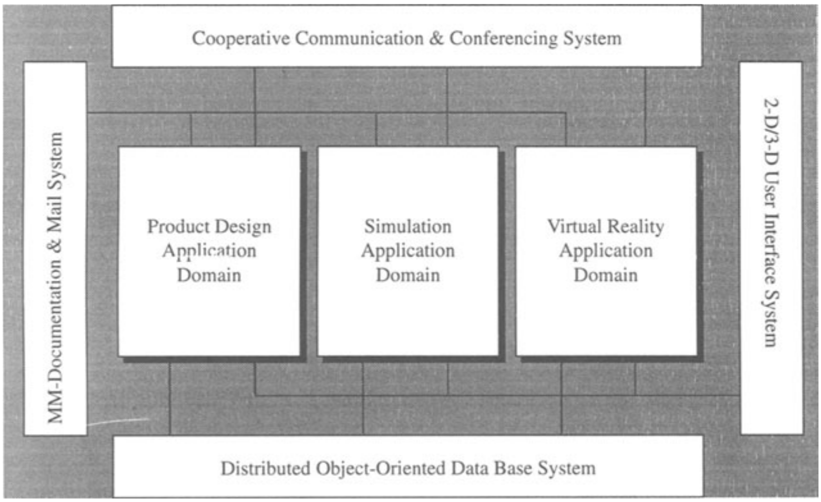

Figure 3: The Virtual Prototype Environment.

are mentioned.

The task of the environment is to offer libraries for the application development process and to provide a set of services for the applications during runtime in the areas of:

- communication and conferencing
  This service provides on the one hand an asynchronous broadcast and point to point message service for communication and on the other hand a synchronous communication service for conferencing. The asynchronous service is used by heterogeneous applications to exchange messages, thus informing each other about a special topic. Here it is important, that the applications are independent and each application decides separately which messages are important for the application and the kind of reaction. The synchronous service is used to support applications in the area of CSCW. Here, the basis services like group management in a conferencing session are provided.
- multi-media documentation and mail
  Integrated documentation becomes an important part of the product development process. The framework provides support for the integrated documentation in the area of dealing and exchanging multi-media objects and to convert and integrate different formats.
- 2-D/3-D user interface
  The user interface system provides services necessary to be able to develop homogeneous 2-D and 3-D user interfaces. Homogeneous user interfaces at the integrated applications raise the acceptance of the end users and help them working in the Virtual Prototyping Environment. Together with the communication and conferencing system, these services enable the development of wrappers to transfer single-user systems into conferencing applications.
- distributed object-oriented data management
  The data management component offers all services for dealing with objects in a distributed environment. The basic goals for the component are to hide the location of an object for the application and to enable a uniform working with transistent and persistent objects. Advanced concepts like working data bases for user session, enabling concurrent access to objects, and check-in/check-out facilities are also topics of this service. To be open for the future, the data base system provides a STEP-based data modeling facility and the object provides an interface in conformance with the SDAI specification [ISO-22].

The integrated applications cover all aspects of virtual prototyping and are grouped in application domains. The virtual prototyping environment consists of the following domains:

- product design
  This domain consists of several CAD-systems for the design of the product. These systems are either geometry-based or feature-based. The purpose of this domain is to create the initial parts of the product.
- simulation
  The simulation domain embraces applications for the physical simulation and also for the analysis of the product.
- virtual reality
  The modeled products are put into the virtual reality domain to be presented in an advanced virtual environment. The virtual reality domain provides also the environment for the visualization of physical simulations or of analysis.
- manufacturing process design
  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.

While these application domains cover mainly all aspects of virtual prototyping, the environment is not limited to these. It could be extended into other directions. Not mentioned in the figure are the domain neutral applications. The purpose of these applications, e.g. the cockpit or the session manager, is to provide functionalities to the user which are needed to deal with the environment, but they are not related to a certain application area.

4 REALIZATION

The Fraunhofer-Institute for Computer Graphics (IGD) and the Fraunhofer Center for Research in Computer Graphics (CRCG) initiated a project for setting up a Virtual Prototyping Environment (see also [HaJa-94], [JKR-94], and [JKSU-94]). In the current state of the prototype, we use also several commercial tools and systems for the environment and in the application domains. The prototype works in a heterogeneous hardware environment, where different applications run on different platforms.

The first prototype supports the messaging between the applications by a communication system. This is based on ToolTalk (SunSoft) and supports messaging in local area networks. The set of used messages is oriented towards those defined in the CAD Framework Initiative (CFI) [CFI-92]. For new applications, we use Tcl/TK (University of Berkeley) for the user-interface. The data management bases on the commercial object-oriented data base Versant (USA). For the underlying product data model, we use the application protocol (AP) Configuration Controlled Design [ISO-203] as the basis. For aspects, which are not covered by this AP, we define extensions for dealing with this data.

For the administration of the environment and serving as the entry point, we implement an

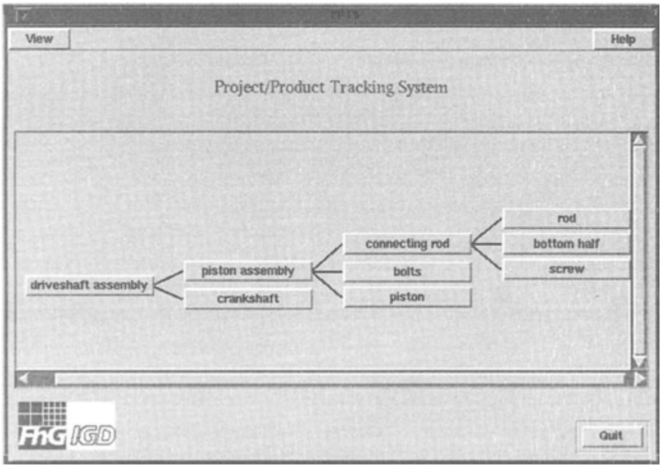

Figure 4: The interface of the Product/Project Tracking System.

application called cockpit. It serves for the designer as the entrance into the Virtual Prototyping

Environment and presents him, besides other information, the list of projects he is participating in. To simplify the work of a designer and to provide control to the data, the entry to a product for the designer is realized via a Product/Project Tracking System (PPTS). The interface is shown in figure 4. Here, the product structure is visualized to the designer, in this case a drive-shaft assembly. By pressing the buttons the designer could initiate different actions. The first action is the retrieval of additional information about one part, like identification number, material information, or the responsible person.

Another action could be the design of a part, which initiates the start of an integrated CAD-System. In our first prototype, we use CATIA (Dassault Systemes, France) as a commercial system.

The designer could also start a discussion about a specific aspect of the product. The environment supports the designer by offering him a list of possible discussion partners, the start of the discussion tool 3D CAD Viewer (figure 5), and the preparation of the data. The CSCW functionality of the 3D CAD Viewer includes shared viewing and annotation capabilities. Shared viewing means that view modifications made by one user can be seen by all partners of the conference. Annotations to the shape e.g. specific markers can be made by all partners simultaneously to support the discussion. The 3D CAD Viewer provides also enhanced visualization capabilities for 3D geometrical data in combination with additional organizational data. This means that not only the geometry will be visualized, but also the approval status or change requests for the product parts. The 3D CAD Viewer consists of two major parts, the data reader and the interactive viewer. The data reader reads the data from the database. The interactive viewer allows high quality visualization of the geometrical shape. The user can modify viewing, lighting and shading parameters interactively.

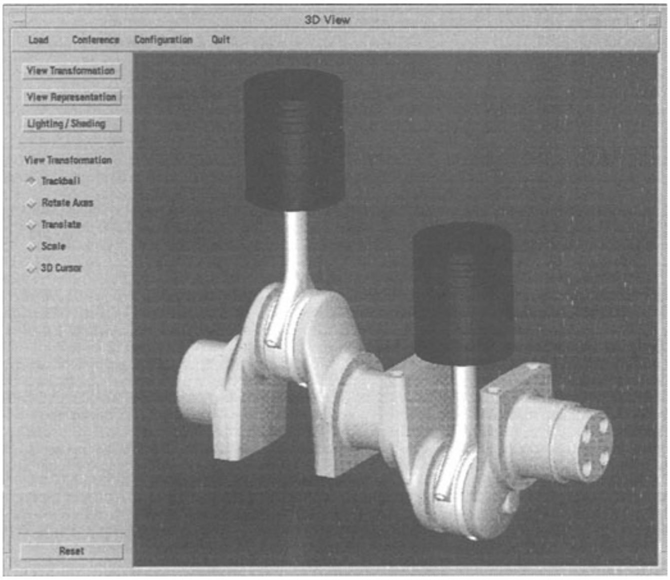

Figure 5: The 3D CAD Viewer showing the driveshaft assembly.

Currently, the advanced visualization of the product data with Virtual Design [AFM-93] is not fully integrated. Nevertheless, Virtual Design is able to read and visualize the exported product data. For the driveshaft assembly, Virtual Design offers a stereo projection of the data and a behavior animation of the assembly.

5 CONCLUSION

The paper described the benefits, concepts, architecture, and components of a Virtual Prototyping Environment. The described environment contains several major features. One feature is the availability of a common, distributed data repository, which stores the relevant data of the design process according to the Application Protocol 203 *Configuration Controlled Design* of the ISO 10303 Standard STEP. The access methods to the objects in the data repository are based on the *Standard Data Access Interface* specification of ISO 10303. The adoption of standards is a central objective for a Virtual Prototyping Environment and ensures the openness of the environment for future developments.

Features of the first prototype are browsing and editing applications for the product structure and the project context. For the design task, a commercial CAD-System is integrated. To enable synchronous communication among not co-located persons, CSCW tools as components of the Virtual Prototyping Environment were introduced.

The presented environment represents an open, extendable framework for the integration of engineering applications. Future extensions to the environment can address the underlying information model as well as the integration of applications which support specific tasks in the process chain of product development, such as kinematic or FEM analysis. The underlying data model can be extended by integrating additional STEP schemata. Thus, the whole data model of the prototype will develop in the direction of an integrated product model.

The described Virtual Prototyping environment supports concurrent design and integrates CAD systems in a heterogeneous computing environment. Nevertheless, the concept is open for the support of the whole engineering process as well as other application areas, e.g. Electronic Design Automation. Considering other approaches in the manufacturing area described by Kimura [KIM-93] who presented a total manufacturing integration by a virtual manufacturing concept the idea of Virtual Environments will be adapted to the whole enterprise.

6 REFERENZES

[AFM-93] P. Astheimer, W. Felger, S. Mueller: *Virtual Design: A Generic VR System for Industrial Applications*; in: Computer & Graphics, Vol. 17; No. 6; pp. 671-677; 1993.

[CFI-92] CAD Framework Initiative: *Intertool Communication Architecture*; CFI Pilot Release Document CFI-92-P7; 1992.

[KIM-93] F. Kimura: *Virtual Manufacturing as a Basis for Concurrent Engineering*; IFIP TC5 Conference Towards World Class Manufacturing; September 12-16, 1993; Arizona, USA.

[HaJa-94] S. Haas, U. Jasnoch: *Cooperative Working on Virtual Prototypes*; in Proc. of the IFIP 5.10 Workshop on Virtual Prototyping; Providence, USA; 1994.

[HKF-93] E. J. Haug, J. G. Kuhl, F. F. Tsai: *Virtual Prototyping for Mechanical System Concurrent Engineering*; in Concurrent Engineering: Tools and Technologies for Mechanical System Design, Ed. E. J. Haug; pp. 851-879; Springer 1993.

[ISO-1] ISO/IS 10303-1: *Industrial automation systems - Product data representation and exchange - Part 1: Overview and fundamental principles*; International Organization for Standardization; Geneva (Switzerland); 1994.

[ISO-21] ISO/IS 10303-21: *Industrial automation systems - Product data representation and exchange - Part 21: Implementation methods: Clear text encoding of the exchange structure*; International Organization for Standardization; Geneva (Switzerland), 1994.

[ISO-22] ISO/CD 10303-22: *Industrial automation systems - Product data representation and exchange - Part 22: Implementation methods: Standard Data Access Interface Specification*; ISO TC184/SC4 N225; National Institute of Standards and Technology; Gaithersburg (MD, USA); November 1993.

[ISO-203] ISO/IS 10303-203: *Industrial automation systems - Product data representation and exchange - Part 203: Application protocol: Configuration controlled design*; International Organization for Standardization; Geneva (Switzerland); 1994.

[JKR-94] U. Jasnoch, H. Kress, J. Rix: *Integrating Applications into a Virtual Prototyping Environment*; in Proc. of the IFIP 5.10 Workshop on Virtual Prototyping; Providence; 1994.

[JKSU-94] U. Jasnoch, H. Kress, K. Schroeder, M. Ungerer: *CoConut: Computer Support for Concurrent Design Using STEP*; in Proc. of the IEEE Third Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises; Morgantown, 1994.

7 BIOGRAPHY

Uwe Jasnoch received his university diploma in Computer Science from the Technical University of Darmstadt in 1989. Then, he was a software engineer with Philips Kommunikations Industrie AG for one year. Afterwards, Uwe Jasnoch was a researcher with the Interactive Graphics Systems Group at the Technical University of Darmstadt, where he was involved in several R&D projects. Since 1992, he has been a researcher with the Fraunhofer Institute for Computer Graphics in the Industrial Applications Department. His main research topics are data modeling, open environments, and consistency management.

Holger Kress is a researcher in the Industrial Applications Department of the Fraunhofer Institute for Computer Graphics since 1991. He is currently involved in research projects in the area of product modeling, groupware, and CAD frameworks. He received a masters degree in mechanical engineering from the Technical University of Darmstadt in 1991. His research interests include concurrent engineering, product modeling, and computer supported cooperative work.

Dr. Joachim Rix is head of the department for Industrial Applications of the Fraunhofer Insti-

tute for Computer Graphics (IGD) in Darmstadt, Germany. From 1991 to 1992 he was Associate Manager of the Fraunhofer Computer Graphics Research Group (today; Fraunhofer Center for Research in Computer Graphics, Inc. (CRCG) in Providence, RI). Mr. Rix received his Diploma and Ph.D. in Computer Science from the University of Darmstadt. His topics of interest are in Computer Graphics, CSCW, CAD, and Product Modelling. This includes the integration and use of computer graphics with its presentation and interaction techniques in industrial applications, like CAD, CAM, Concurrent Engineering , and Groupwork Computing. Mr. Rix is member of the standards Committee of ISO/IEC JTC1/SC24 „Computer Graphics“ and was Rapporteur of the study group „PREMO“ (Presentation Environments for Multimedia Objects). Since 1985 he is member of the national and international committees (DIN NAM 96.4, ISO TC184/SC4) developping STEP (Standard for the Exchange and Representation of Product Model Data). Since 1994 he holds the position of a deputy convenor of its WG 3 „Product Modeling“. Since 1981 Joachim Rix is member of the Eugrographics Association.