Pragmatic Approach to Apply Virtual Reality Technology in Accelerating a Product Life Cycle

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ABSTRACT

Today, industries are facing tremendous pressures from the global economy, the increase of customer expectations and demands, and the exponential increase of product complexities, to name a few. To survive in the competitive market, the industries need to develop innovative products and increase product quality while decreasing product costs and shortening time-to-market. In order to remain competitive, the companies have been making their efforts to reduce operating costs and make product development efficient and effective by applying computer technology and introducing new design methodologies and processes. Virtual reality (VR) and virtual prototyping (VP) techniques are the novel technologies that the cutting-edge organizations are willing to adopt in developing and manufacturing their products. Even though these computer technologies are promising, simply adopting them can not bring an organization benefits because they are still under extensive development and have not overcome some limitations. Thus, by taking successful project examples which were conducted by Fraunhofer Institute for Factory Operation and Automation, this paper analyzes current computer interactive visualization technology and discusses how VR and VP should be applied in product development and a product life cycle.

Keywords: Virtual Reality, Virtual Prototyping, Product Development, Product Life Cycle, Productivity, Training

INTRODUCTION

It has been said that development of new products is taking place in a harsher environment ever because market demands and product complexity have significantly increased and the environment for developing new products have rapidly changed. To survive and lead the market, industries have introduced new design methodologies, new manufacturing processes and new computer technologies to their product development practice. Computer visualization is one of such emerging technologies.

As computer technology advances, computer visualization has been increasingly applied in the product life cycle—design reviews, simulations, communications, trainings, and so on. These computer visualization techniques used in product development are usually known as Virtual Reality (VR), Virtual Prototyping (VP) and Digital Mock-Up (DMU) and help organizations to produce innovative products for competitive prices and in shorter time-to-market.

This paper first presents an overview of product development methodologies and a product life cycle and discusses popular VR applications in the product life cycle. Then, the VR system developed by the Fraunhofer Institute (IFF) and its concept are briefly introduced. Finally, with IFF's project as an example, pragmatic use of VR technology is described.

VR APPLICATIONS IN A PRODUCT LIFE CYCLE

The product life cycle, as shown in Figure 1, starts with marketing, goes through several product development stages and ends with recycling and disposal of the product [2]. Traditionally, the product life cycle stages are sequentially carried out by experts. This engineering design practice has difficulties to satisfy industrial needs and operations in an environment where cost, quality and time parameters are much more demanding than ever before [3]. Since the late 1980s, product design activities have been concurrently carried out. This is known as concurrent engineering or simultaneous engineering. This design methodology is used to achieve three general design objectives—to make a product of the highest level of quality and performance, to minimize the cost, and to attain the shortest time-to-market [4]. The main driving force of concurrent engineering is the rapidly emerging computer technologies and integration of the computer tools. Some of the computer technologies which are well accepted in design activities are computer-aided design (CAD), computer-aided engineering systems and computer simulations. However, they have been developed since 1960s and might not be able to address today's product life cycle needs. For instance, CAD is designed to be used in the limited stages of product development and its interfaces are too difficult for everyone except for the designers who work with it everyday. Recently, VR and computer visualization have been emerged to address CAD limitations through the product life cycle needs.

The term "virtual reality" is broadly used from simple visualization of 3-D models on a computer monitor (non-immersive) to representation of the models with stereo glasses (semi-immersive) to depiction in a fully immersive environment (See Figure 2). An example of non-immersive VR can be seen in the use of VRML in which one can navigate through 3-D world with a mouse and a keyboard in real-time, while the fully immersive virtual environment might be consisted of a CAVE with a head tracking system and/or data gloves.

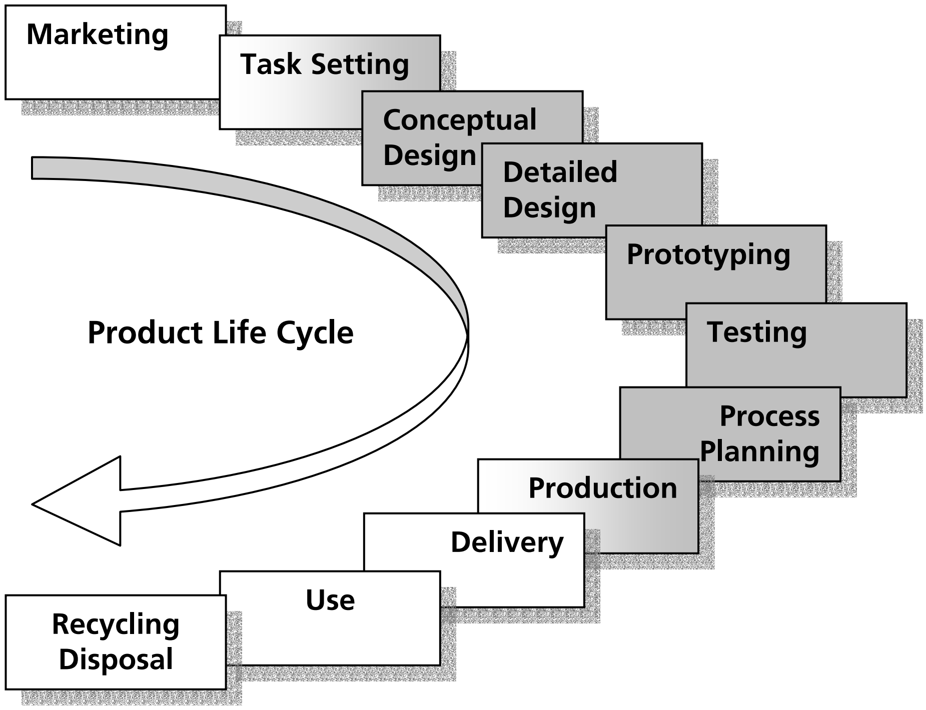

Figure 1. Product life cycle

Non-immersive Semi-immersive Fully-immersive

Figure 2. Virtual reality. Reprinted from IFF's brochures.

Also, the term "virtual" implies that the final form of a design concept is not yet generated, but the geometric representation of the concept is shown for visualization, analysis and manipulation [5]. The models visualized with VR technology are often called virtual prototypes and can be formally defined as the creation of a simulatable digital mock-up which resembles a physical one in terms of looks, functionality, behavior, haptic, kinematics and dynamics. VR's applications have been employed in various industries; e.g., aerospace, automotive, shipbuilding, marine, biomechanics, defense, machinery, sports and entertainment, and they are spread to all phases of a product life cycle. Unlike other computer technologies, VR is widely employed in the product life cycle because it addresses all the requirements from each product development stages—its capability of solving engineering design concerns of the developer, process concerns of the manufacturer, logistical concerns of the maintainer, and training and programmatic concerns of the operator. Some of the tasks which VR can deal with are listed in Table 1.

Table 1. VR in a product life cycle

Product Life Cycle	Marketing	Presentations, Documentation
	Task Setting	
	Conceptual Design	Design reviews, Concept validations, Design comparisons
	Detailed Design	Part modeling, Assembly modeling
	Prototyping	Design optimization, Shape optimization and topology optimization
	Testing	Simulations, Feasibility test, Tolerance, Part or system interaction, Motor operation and ergonomics
	Process Planning	Fixture design, Job planning, NC programming, Training
	Production	
	Delivery	Logistic planning
	Use	Training, Documentation (trouble shootings, user's manuals)
	Recycling/Disposal	Disassembly simulation and planning

The use of VR brings many benefits to the organizations. For example, a product development cycle can be much shortened because the number of physical prototypes is reduced, while product quality is improved since modification and corrections of the product idea can be easily implemented. Furthermore, since it enables designers to develop a system as a whole instead of elaborating each component, VR can address total quality management which emphasizes a system level development.

Even though it has had a great impact on product development and the product life cycles, VR needs to address several issues to be used as an everyday-tool since it is still a relatively new technology. Some of these include (1) high initial investments for both software and hardware, (2) necessities of extensive expertise to implement VP, (3) limited outcomes caused by boundary conditions and material states, (4) unexpected results yielded by numerical computation based on engineering theory, (5) troublesomeness of data exchange between dissimilar computer programs, (6) immaturity of tactile feedback, (7) difficulties to have a good sense of size estimation, and (8) abuse of data resulting from computer programs since designers have limited understandings of engineering fundamentals.

VDT PLATFORM

The VR system at IFF is called the Virtual Development and Training Platform or VDT Platform. The Platform's structure is consisted of three core components—a run-time system, an authoring system and a scenario concept. The run-time system is a software package to enable one to represent, navigate and interact objects in a computer environment in real-time. A 3-D model or geometry in this virtual environment is usually created by CAD and imported to the platform. However, geometry does not have purposes of its structure if the information such as functions, kinematics and dynamics is not explicitly specified [6, 7]. The authoring system is used to define all the information to bring geometry to life. The authoring system has a graphical user interface so that an author can intuitively build a virtual world even though he or she does not have profound knowledge in computer science. The result yielded by working with the authoring system is a scenario. In a scenario, the additional information on geometry is modeled in three different levels, as shown in Figure 3. An example of the scenario might be a description of how 3-D models should behave and what happens when the user interacts in a certain way.

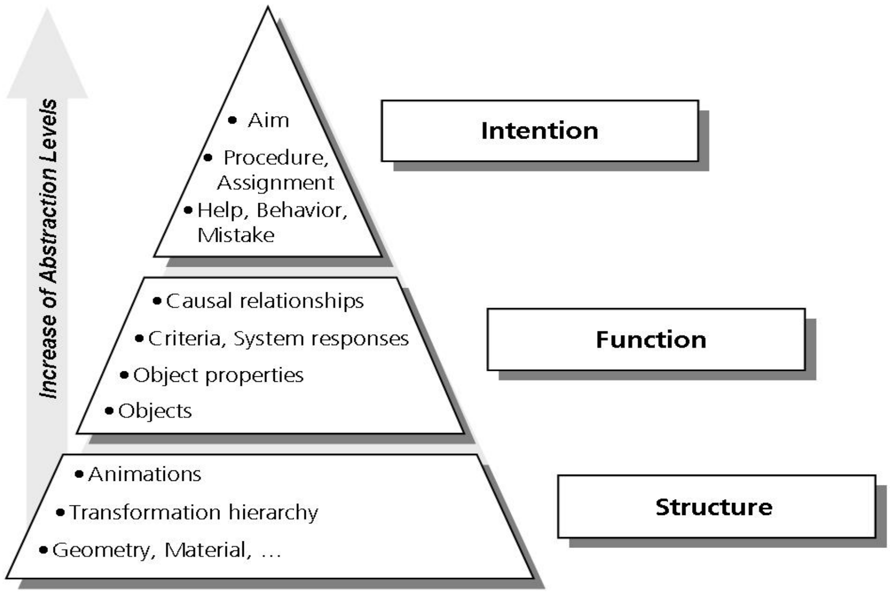

Figure 3. Information levels to define a scenario. Reprinted from [7].

IMPLEMENTATION OF VR

Illustrated with one of the projects carried out by IFF, this section displays practice-oriented applications of VR. The project demonstrated in this section is *Entwicklung innovativer* ***Pro****dukte und* ***Di****enstleistungen unter Nutzung von VR-Technologien für kleine und mittlere Unternehmen des* ***Ma****schinen- und Anlagenbaus* (ProDiMA)[1], which was funded in the program of EFRE[2] Innovative Measures in Saxony-Anhalt, Germany. One of ProDiMA's objectives is to make the machine and plant engineering and construction industry in Saxony-Anhalt innovative and competitive by solving its problems arisen in product life cycles with VR technology. Figure 4 shows on which stages of the product life cycle the project focused.

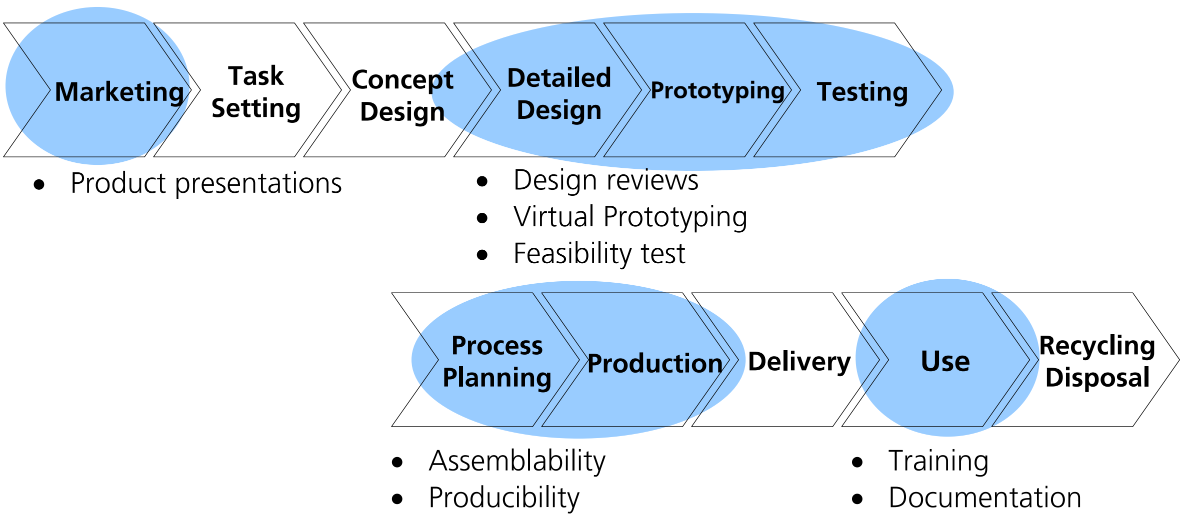

Figure 4. VR in a product life cycle

[1] engl.: "Development of Innovative Products and Services for Small and Medium Sized Manufacturing Enterprises by Using Virtual Reality Technologies"
[2] Europäischer Fonds für regionale Entwicklung or European Regional Development Fund (ERDF)

In the marketing stage, the VR solution can effectively support presentations of a complex machine system, as shown in Figure 5. Not only can potential customers examine the machine system by flying through a computer environment, but also complex functionality can be clearly highlighted. A VR presentation has a great advantage over video presentations. This is because machine capabilities can be shown in the way that the customers want to see; e.g., a possible process to increase the customers' productivity. On the other side, the video can demonstrate how the vendor desires to show their product.

Figure 5. VR in the marketing stage

The use of VR in the product development stages such as concept and detailed designs, prototyping and testing gives the designers great insights into their designs. The designers, for example, can readily identify design mistakes which are not foreseen in the stage of defining functionality (e.g., collisions). Moreover, computer visualization can be used to optimize designs especially regarding to ergonomics. In ProDiMA, an operator's views from the cabin were optimized, as shown in Figure 6.

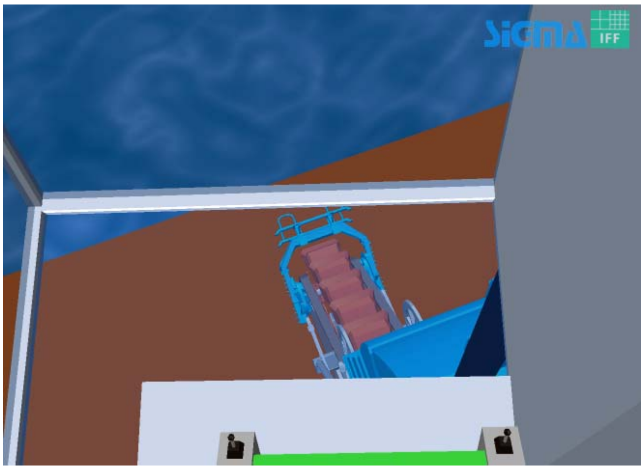

Figure 6. VR in the product development stages

In process planning and production, VR can be applied to optimize an assembly process, a factory layout and producibility, to mention a few. ProDiMA aimed at investigating whether a product was able to be built in a limited space (See Figure 7).

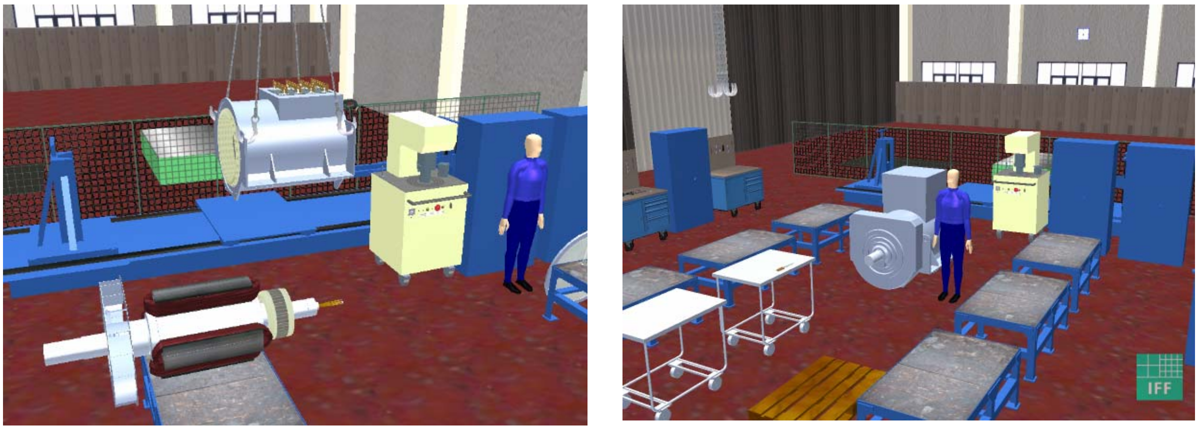

Figure 7. VR in the production stage

In later stages such as use in Figure 4, the visualization techniques greatly help documentation issues. Product documents and data can be managed with 3-D models so that the user can intuitively administrate product information, as illustrated in Figure 8.

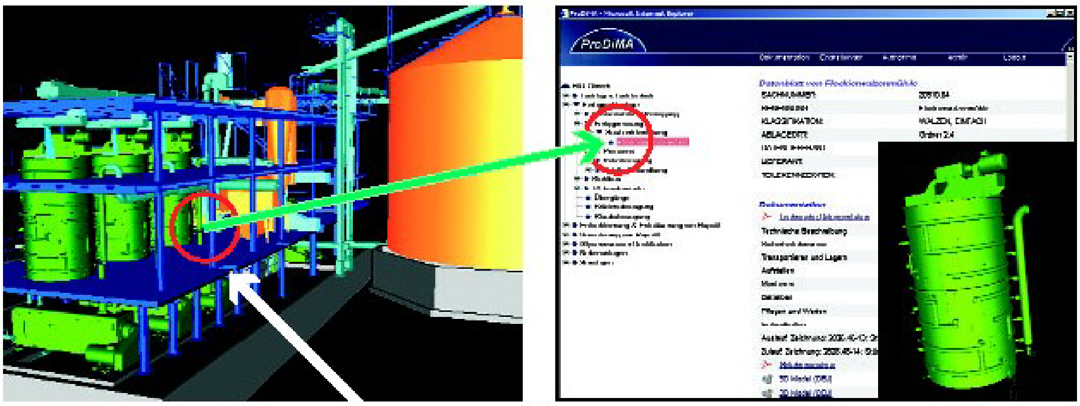

Figure 8. VR for product documentation. Reprinted from IFF's brochures.

Another important application of VR in the late product life cycle is training and qualification of product end-users. VR-based training is appropriate when the products have a number of variations and changes, training facilities are limited, the expert knowledge on the products is required, and the cost of equipment is high. It supports a trainee's learning process step by step [8]:

- Knowing the structure of the system or plant by navigating vertically and horizontally through the hierarchy of assemblies.
- Understanding the functions of the technical system by complete, real-time animations. To show the point of interest, transparencies or different types of highlighting are used.
- Training of manipulative actions (maintenance, assembly, repair, etc.).
- Training of diagnosis and repairs by generating a situation by hiding a fault in one substructure.

The implementation of VR-based training brings the organizations many advantages such as reducing and saving the training time, providing a better transfer of expert knowledge, increasing operator safety, minimizing the risk of machine damage and breakdown by mistakes, and training personnel under extreme situations [9]. ProDiMA has enabled one to learn operations of a highly complicated machine in a trial-and-error manner. Moreover, the project has produced a training platform for assembly workers.

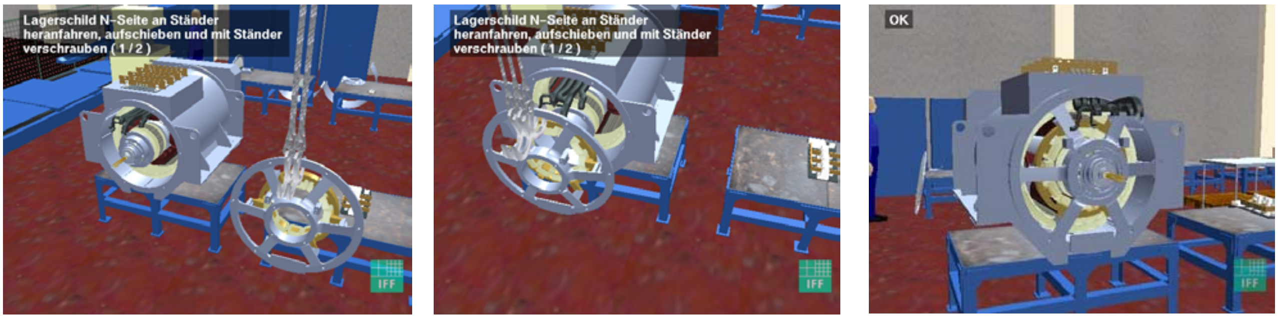

Figure 9. VR in training

ProDiMA finished successfully and contributed to helping the SME industry in Saxony-Anhalt to become competitive and innovative. In fact, the project received a European Regional Innovation Award from the European Commission in 2004.

SUMMARIES

VR has been gaining its popularity in all the phases of a product life cycle; e.g., marketing, developing, manufacturing and maintaining products. The main objective of using VR technology is to increase quality of the product and its service while reducing product cost and time-to-market. In this paper, VR applications in the product life cycle are discussed. Furthermore, the VDT platform, IFF's own VR system, was briefly introduced. Finally, the paper described how the VDT platform addressed issues in a product life cycle with award winning project ProDiMA as an example.

In conclusion, it was shown that VR technology can be applied in the entire product life cycle and provide manufacturing companies for advantageous solutions. Computer visualization can be applied not only the machine and plant engineering and construction industry but also any other sector of industry.

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