Industrial applications’ simulation technologies in virtual environments
Part 1: Virtual Prototyping

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Abstract: Virtual Prototyping could be considered as a general term, since it pertains to both processes and products. Nevertheless the term has prevailed to be used in applications for the development of Virtual Prototypes for products. In the Virtual Prototypes that are developed with the use of Virtual Reality technology, functional verifications could be implemented for the determination of quantitative and qualitative parameters of the product. A definition has been formed for the Virtual Prototyping technology, according to the applications that have been introduced and the results from their employment. Also some of the most significant systems contemporary developed have been indicatively reported, in order to clarify the subject and the potentials of the technology as a simulation tool in industrial environments.

Keywords: Virtual Prototyping, Virtual Reality, Virtual Environment, Industrial Simulation
1. INTRODUCTION

Product performance and production simulation constitute an essential part on every product design process. For the determination of production processes parameters, Virtual Manufacturing and Virtual Assembly technologies are been utilized. Virtual Prototyping technology is employed for the determination of parameters related with the product performance. These three technologies require different techniques and methodologies for their implementation, but they also have common characteristics, such as the exploitation of computer graphics technology and common aim, which is the determination of crucial parameters for the product development process.

Below, a definition for the Virtual Prototyping technology is provided based on the applications that have been developed. In addition, typical examples of Virtual Prototyping systems, which have been developed in research level or are been exploited in real industrial environments, are reported.

2. VIRTUAL PROTOTYPING

Companies during the design phase, develop product prototypes with various methods for studying products’ critical characteristics, for customers’ feedback to the design team, etc. In these prototypes (Virtual or physical), a number of functional inspections are implemented. These inspections aim at design errors determination. The results of the inspections feedback the design process and the required modifications are accomplished. This process is repeated until the product reaches an appropriate maturity level to be introduced in the market, subject to time and cost constraints for the completion of product design.

Virtual Prototyping technology therefore is focused in the product and aims at the reducing the required number of physical prototypes, which are developed during the product development phase. At the same time, technology provides capabilities for quantitative and qualitative parameters evaluation, like:

- Product visualization and aesthetics evaluation (these composed the first applications).
- Product dynamics and kinematics characteristics.
- Product study in working conditions and behaviour.

The use of immersive peripherals (Virtual Reality head mounted display, data glove, etc.) in the virtual environment is essential mainly in applications for aesthetic parameters and functional characteristics evaluation, since the interaction between the user and the virtual environment, constitutes the most crucial system characteristic for the determination of the desired product parameters.
2.1. Virtual Prototyping applications

One of the first applications was created in 1996, when the Renault company presented a very impressive video called Les Citadines [1] (Fig. 1). In this video real world pictures were combined with Virtual Prototypes of companies models (Augmented Reality), which were under development.

![Fig. 1. Snapshot of the Renault video](image1)

![Fig. 2. Chrysler suspension absorbers fatigue verification](image2)

In the early stages of Virtual Prototyping technology, it provided only capabilities for product visualization. Later functional characteristics simulation, like kinematics behaviour, etc. was feasible. Today, most automobile companies, like General Motors, Chrysler and Ford [2] use Virtual Prototyping technology not only for functional, but also for technical characteristics simulation of their products. For this purpose they have developed hybrid analysis models, where part of data is acquired by physical prototypes and the rests is created in the computer. Ford [3] reports that it accomplished to reduce the development time of a mechanism, which controls automobile’s stability, from 8 months to 1 week. B.F. Goodrich Company [3] aims in strategic level at 50% reduction of the design time, which would result in 35% product cost reduction. Daimler-Chrysler (Fig. 2) has decreased measurements cost for each new suspension study at roughly $1500-$2000 with simultaneous testing time reduction. Chrysler [4] develops Virtual Prototypes for all its products (Fig. 3). According to Chrysler, for the development of a physical prototype, 6 - 8 weeks are required, while the development of a Virtual Prototype requires less than 1 day.

Finite Elements analysis composes a crucial parameter of a Virtual Prototype system [5]. Schulz, Reuding and Ertl [6] in cooperation with BMW have developed a Virtual Reality system for the determination of the individual automobiles parts behaviour in different impact types (Fig. 4). System users have visualization capabilities for the impact and the way the automobile deforms. They can also interact with the geometric models, create sections in various geometric models’ planes, etc. Similar research is being accomplished by GM through “Math-Based Synthesis-Driven Vehicle Development Process”, which intends at integrating in a single virtual environment all the mathematics models developed for functional characteristics determination and company’s sales and business parameters. The
objective of the research is to reduce development cost and time, to improve product quality and to increase the innovation level of the company. With this project the company has increased by 300% the number of executed impacts and has decreased the waiting time for results issue at a factor from 6 to 60.

Caterpillar [7], [8] has developed one of the most well known Virtual Prototyping applications in a CAVE system (Fig. 5, 6). In the CAVE environment a virtual driving seat with force feedback capabilities has been created and excavator and trucks prototypes are included in a virtual world with specific formation, in order to provide excavation works simulation capabilities. The application is used for company's new products ergonomic parameters study, like visibility and instruments reachability and for personnel training in the vehicle operation. Data provided by the system are used in the design process for errors correction. The system could be simultaneously accessed from many users, though network.

Boeing employed Virtual Prototyping for designing the 777 airplane [9]. The intension of the company was to create a digital product (Fig. 7), allowing the application of Concurrent Engineering techniques. Boeing considerably improved the design process, according to the evaluation the company accomplished after the end of the process. The Virtual Prototype of the aircraft provided walk through and parts assembly feasibility tools to the user. As a result in the 777 developments the
average design changes were reduced from 4.5 to 1.2, which led to product cost reduction and to product quality improvement. Moreover, the company exploited the use of Virtual Prototype for product promotion to its customers, since it provided product visualization capabilities with the specific characteristics each airline company required. These characteristics are evaluated before the order placement and the aircrafts are built afterwards, according to every customer requirements. The specific application considerably reduced the requirements for physical prototypes construction. Only a few aircraft parts were constructed, like the pilots cockpit, which is evaluated by the company customers, scaled models for aerodynamic parameters study and other individual parts. In the company future objectives is the integration of all the product functional characteristics, which will allow the simulation of the entire aircraft behaviour. This model will allow the analysis of parameters, like the possibility and the repercussions from various types of engine failures or failures in other parts of the aircraft.

Airbus exploits Virtual Prototyping technology, in a different way to Boeing. For the model A380 design [10], which will be the top of the line company model when it will be available in the market in 2004, Airbus employs the EADS CCR software design tool. This software has low computational power requirements and it could operate in a common PC workstation (Fig. 8). EADS has been developed with the Sense8 World Toolkit Virtual Reality applications development tool. The main criterion for the EADS CCR software development was convenience, in order to be exploited by engineers without CAD systems experience. This criterion was placed by Airbus, since many engineers participating in the product development process do not use CAD systems. In the Virtual Prototype that is developed during the product design process with the use of these tools, alternative scenarios are being studied, aiming at the reduction of the required space for the main aircraft parts, in order to increase its transportation facilities and to determine the location of critical aircraft parts, for the reduction of consequences in case of explosion. EADS CCR is being developed, in order to provide simultaneous access to different users through network, for direct product data processing during meetings or the fulfilment of meetings from distant locations.

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Fig. 8. Virtual Prototyping in Airbus
3. CONCLUSIONS

Evaluating the applications described above, Virtual Prototyping technology shows adequate maturity, regarding product characteristics simulation, none the less not all the existing problems and restrictions have been confronted. It should be noted though that the integration of graphics technology with simulation models composes a powerful tool for the designers. Nevertheless applications development remains a time-consuming and difficult process. In the near future it is expected that all product data with be digitally formed, which will constitute the beginning for all the product development software integration and the creation of a virtual factory, where the entire production process will be simulated. Virtual Prototyping technology aims at reducing production cost and time and at improving the final product, by providing to the designers information about the product that greatly contribute in improving design comprehension, locating technical problems and satisfying to a higher degree the predefined specifications. At the same time it composes a significant user introduction and training tool in the future applications.

References