

From High-End VR to PC-based VRML Viewing: Supporting the Car Body Development Process by Adapted Virtual Environments

Martin Schulz ^{†‡}, Edith Zimmermann [†], Thomas Reuding [‡], Thomas Ertl [†]

[†] University of Erlangen, Computer Graphics Group (IMMD IX),
Am Weichselgarten 9, D-91058 Erlangen, Germany

[‡]BMW AG, Entwicklung Karosserie, 80788 Munich, Germany
Email: schulz@informatik.uni-erlangen.de, thomas.reuding@bmw.de

CR Descriptors: Virtual environments, VRML, scientific visualization, finite elements

Abstract

In order to improve the vehicle development process numerical simulation techniques are used to achieve earlier and better concept validation. These simulations produce large 3D time-dependent data sets of geometry and physical related properties. The engineers have to analyze these results and improve the vehicle in cooperation with the responsible designers. The use of virtual reality techniques can enhance several post-processing steps of result examination. This work presents different adapted virtual environments for individual post-processing tasks. The environment types range from VRML based viewing to full immersive VR. We will show which kind of environment fits the needs and we will give examples from the on-going work at the University of Erlangen and BMW.

1 Motivation

The concept phase of product development in automotive design is characterized by the need to evaluate complex engineering scenarios as early and as fast as possible. Virtual prototypes and numerical simulations allow optimization of the design long before results of real prototype tests are available.

Numerical analysis in car body engineering extends to a variety of different fields such as structural mechanics, aerodynamics, acoustics, fluid dynamics, to name just a few. The model complexity and the increasing amount of transient data sets complicates the analyses and communication of the results.

The vehicle development cycle can be partitioned into two important parts. First, the finite element analyst builds the numerical model, performs the simula-

tions and interprets the calculated results. Second, the engineers have to discuss detected design shortcomings with the responsible designers. Momentarily standard 3D post-processing techniques and 2D images are used to support these activities.

Further difficulties are due to the fact that people of different expertise and background have to assess the data and evaluate the performance predictions and functionality of a design. New visualization techniques are required to solve these conflicts.

The development in computer hard- and software allow the use of virtual reality techniques in industrial applications. New high level graphic APIs and new graphic systems are the foundation of this approach. Previous research has shown that virtual environments can offer a wide variety of analytical post-processing tools [BS95, BL92, YV97].

The use of the Intra-/Internet for communication within a company or between the company and external suppliers is increasing rapidly. In this context it appears highly attractive to base the distribution of geometry related engineering information on the use of web tools [Mar97b]. In addition, the availability of VRML 97 as new 3D animation standard [LMM96, HW96] can support the decision making process significantly better than the use of traditional 2D representations.

This work presents a new approach to improve the different tasks in the vehicle development process by the use of adapted virtual environments.

2 Adapted Virtual Environments - System Design

Virtual environments have to be configured for the application to become Adapted Virtual Environments (AVE). In table 1 the different hardware equipment and virtual environments for specific development

Application scenario	VE-type	Number of users	Devices
Complete model analysis	VR-lab	1-2	BOOM Tracker Cyberglove
Detailed analysis of components	Work station	1-3	Monitor Stereo glasses 2D-mouse 3D-mouse
Knowledge exchange via Intra-/Internet	Web / VRML	2	monitor 2D-mouse
Decision making meetings	Stereo screen	20-30	Projection 2D-mouse 3D-mouse Stereo glasses
Design Documentation	Web / VRML	1-3	Monitor 2D-mouse

Table 1: Table of different application scenarios and the corresponding Adapted Virtual Environments.

steps are shown. Different application scenarios require appropriate functionality and hardware equipment. For example a fully immersive virtual environment is inapplicable for use in a decision making meeting of 20-30 persons.

Specialized engineers use a full immersive AVE for a fast inspection of the complete model. To speed up their work direct interaction with the model and intuitive navigation are offered. Design shortcomings can be easily recognized. Further analyses of model subsets can be done in an AVE for the engineer's individual work place. In this case only the 2D- and 3D-mouse are used for interaction. VRML files of vehicle components can be created from this virtual environment.

Decision making meetings can be prepared via the Intra-/Internet by the directly involved engineers. Web tools like *CosmoPlayer* offer an easy to use visualization possibility. People without a knowledge of specific post-processing methods are able to get their own view of the data sets. Stereo projections improve the discussion and decision making in meetings between the engineers and designers. Up to 30 persons can get into such a virtual environment. Finally, for the documentation of component's design evolution different development states can be collected on HTML pages.

In the on-going cooperation between the University of Erlangen and *BMW* a visualization system for automotive simulations is under development [KSE⁺97, SRE98]. Figure 1 shows the system structure. It is divided into a high-end VR part and a VRML based part for Intra-/Internet access.

The high-end part includes the VR-lab, the work place environment and the projection environment. This part of the system also contains methods for con-

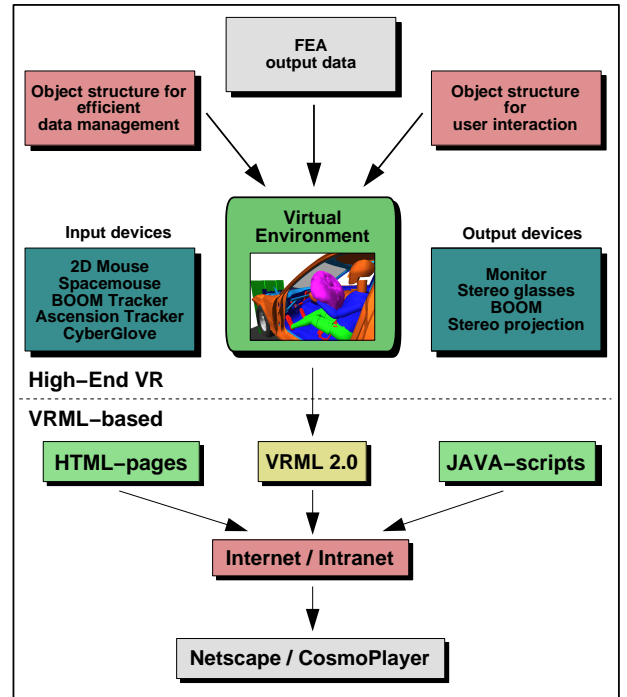


Figure 1: Structure of the visualization system

verting finite elements into geometry information and for creating VRML files of selected vehicle components. Workstations like *SGI ONYX* and *Octane* fulfill the requirements of graphic performance and memory space.

The VRML files can be used for documentation and communication. The benefits in the second part lies in the link between the expensive high-end environment necessary for the scientific engineering computations and the widespread available low-cost workstations and PC's. Adding JAVA scripts and HTML pages to the created VRML files allows to propagate the analyzed results to each involved engineer. The JAVA scripts and HTML pages control the visualization in the web browser.

3 Evaluating Numerical Simulations in a High-End Virtual Environment

This part of our visualization system is able to directly load results of different finite element simulations, such as impact dynamics, vibrations and acoustics, and generates 3D animations of the scenario at interactive rates. A variety of different interface and interaction hardware is supported to adapt the virtual environment to the required level of immersion.

The finite elements are transferred into polygonal geometry data to illustrate the performance of the whole vehicle or any subset of components. An average model consists of 300.000 finite elements and about 60 time steps. To handle this amount of geometric information a specialized polygon reduction is

used to cut down the number of polygons in half. This increases the display rates and reduces the memory requirements. At computation time physical properties data like stress, strain and acceleration are calculated. Time-dependent scalar values are displayed as colors onto the components surface.

In case of acoustics simulation the visualization of air pressure volumes inside the passenger compartment requires more complex techniques. Isosurfaces are one way to display the frequently changing air pressure values. Another method is to show the air pressure values mapped onto the volume hull, allowing the engineer to analyze how the vehicle structure and the acoustic volume are interacting.

Besides the traditional interactions like picking, moving, disabling and enabling a component also more complex interactions are implemented. The user can place a cutting plane through the vehicle components for online intersection calculation or select a finite element for evaluation of its scalar values on the virtual sketch pad. A reference plane can be placed inside the vehicle for "on-the-fly" intrusion calculation. With this interaction the engineers performing in an impact simulation can check the depth of intrusion in respect to this plane. For a closer inspection of the temporal behavior of components the viewpoint can also be locked onto selected vehicle parts. Moving in the local frame of the model gives the user new ways of viewing their data, e.g. from a drivers position.

Other application scenarios can be prepared by saving subsets of the model as VRML files. The high-end part can create VRML 97 files just by selecting a component and adding it to the file (Figure 2).

4 VRML/HTML as a Decision Making Platform

Within the automotive development cycle, design decisions are made at many locations on different topics. A platform is needed that offers the possibility to combine 3D geometry and text informations with an easy-to-use interface. HTML pages and VRML files fulfill these requirements and support the decision making process between the involved engineers, designers and managers.

The 3D VRML world consists of explicitly selected geometrical objects, composed of hierarchically structured data, together with physical analysis data, represented as colors mapped onto the geometry of the objects (Figure 3). In addition, the virtual objects might be attached to annotations, like links to web pages containing informations about parameters of the real world test environment or variables of the numerical simulation run.

In order to assign the VRML world with the same functions and features as well as the visualization ca-

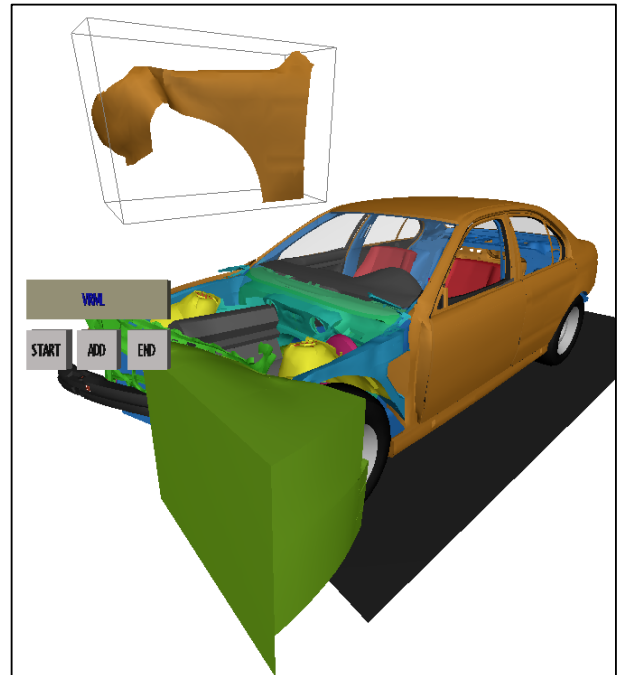


Figure 2: Creating a VRML representation of a selected component from within the immersive high-end AVE.

pabilities of high-end AVE, we have to fulfill a series of tasks. The geometric models have to be ordered in a structured tree, in order to allow the interaction within the scenes as well as the animation of the scene. Hence the data is stored in *GroupNodes*, containing the geometry and the appearance of the objects. For interaction with the model a *PlaneSensor* node is added to the *GroupNode*, to allow "drag and drop" of single parts of the object. Within an *Anchor* the web page with information about the object is attached to the VRML file. To enable the animation of the scene for different time steps, the *GroupNodes* are embedded into a *SwitchNode*. The animation is controlled through a menu, that is created as a *ScriptNode* and added directly into the VRML file making functions such as play, stop, loop, etc., available.

During the development process of car bodies, direct comparison of component variants is necessary. Therefore, two VRML browsers have been combined in one HTML page and routed through the EAI (External Authoring Interface) [Mar97a]. This allows to control the contents of a VRML browser from a JAVA applet (Figure 4).

In order to get a sufficient presentation quality and rendering speed on low-cost workstation and PCs the generated VRML files have to be optimized. With techniques such as employment of prototypes, elimination of white spaces and rounding floating point numbers we achieve a 30 per cent reduction in file size. For reasons of performing optimization during the render-

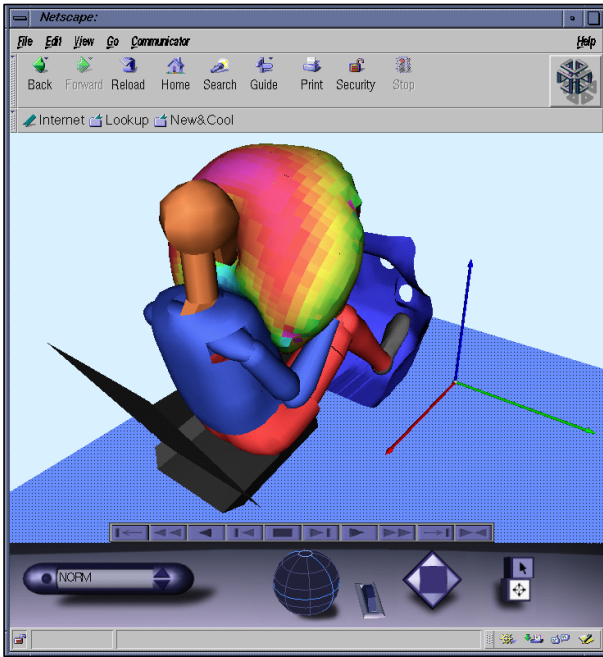


Figure 3: Stress visualization on the surface of the airbag.

ing process, we have divided the scenes into smaller parts. Each geometric object has its own node in a nested hierarchy. Organizing the objects in this way in the scene graph helps the browser to reach higher performance by using viewing frustum culling.

Validation tests with two synchronized VRML browsers have shown that models with up to 20.000 polygons can be animated achieving sufficient frame rate on an *SGI O2*.

5 Conclusions

We presented results of on-going research in the development of virtual environments for car body engineering applications. Our system provides meaningful visualization and intuitive interaction, thus complementing the traditional post-processing with a dedicated tool requiring a high-end graphics workstations. By generating a VRML scene description from selected and possibly complexity reduced components, however, some of the advantages of the virtual environment can be brought to any desktop for documentation, communication, and decision purposes.

Future work will focus on the integration of different visualization techniques within the system. Texture mapping and other graphical advantages are being explored as improved means to display scalar and vector quantities with interactive frame rates. Finally, an even closer linkage of the full immersive virtual environment to the VRML based Intra-/Internet solutions has to be further investigated.

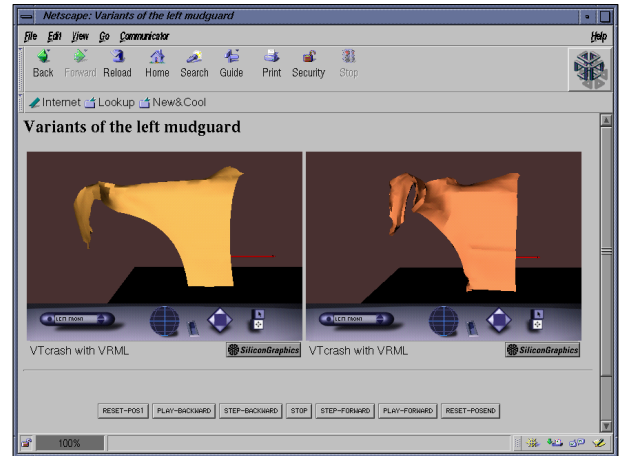


Figure 4: Visualization of two different design variants in two CosmoPlayers within Netscape.

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