Virtual Reality –
New methods for improving and accelerating the development process in vehicle styling and design

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Abstract

This article describes the use of Virtual Reality techniques during the car development process at Volkswagen. A brief definition of Virtual Reality is given and it is pointed out that Virtual Reality has to be understood as a method and not only as a tool.

There will be a short introduction of the research topics that are investigated by the VR-Lab. Some of them will be presented in more detail. It will be shown which steps have to be taken to get a Virtual Reality design review model. The problems are pointed out and possible solutions are described.

An interface to the 3D human model RAMSIS has been implemented. RAMSIS is the result of a joint venture of German car companies and two seat manufacturers. The goal of implementing RAMSIS was to generate a realistic simulation of human beings in car interiors and work places.

The integration of the CAD geometry kernel ACIS enhances the analytical possibilities of our Virtual Reality system by adding the same parametric surfaces used by the original CAD system and providing a wide variety of CAD functionality (e.g. cutting planes, distance measuring, boolean operations).

A 3D interaction model for modifying colors and surface structures of car interiors provides an easy and intuitive access to the geometric models concerned. Arbitrary components can be selected freely within the Virtual Environment and they can be manipulated "by a wave" of the hand.

It is shown that Virtual Reality technology at Volkswagen provides a serious means for accelerating the car development process. Integrated in the daily product development process, VR matured from a "playground of weird scientists" to a mighty tool that helps save time and money.

1 Introduction

1.1 Our understanding of Virtual Reality

Because of the fact that Virtual Reality covers a wide area of possible applications and implies a fundamental enhancement of the human–computer interface (HCI) we rather describe than define our understanding of the term "Virtual Reality". Since we cannot claim to cover all aspects of VR in our research lab, this description will only be valid for in-house applications.

Commonly used interfaces of todays computers are monitors, keyboards and indicating devices (mice or graphic tablets). Even sound output is "state of the art". But as computers are becoming more and more powerful and 3D graphic capabilities are already required for home based personal computers, the interfaces are not as intuitive as they should be. Using a keyboard to enter text into word processing software limits the user, it would be far more natural to speak the words and let the system enter the words into the word processing software.

Monitors are well suited for displaying 2D information such as text documents or spread sheets since the original (a piece of paper) is two–dimensional as well. But when dealing with 3D data (e.g. the model of a car) it is more difficult because all that can be seen on the screen is the 2D projection of a 3D model. Spatial relations of different parts are diffcult to determine due to the lack of depth perception when using a standard monitor.

Virtual Reality implies (literally) that the user cannot distinguish between reality and the machine generated "Virtual Reality". Therefore all of the senses have to be stimulated to obtain a realistic impression. Because of the fact that the human perception relies mainly on audiovisual perception we concentrated on these two senses with haptic interfaces become more and more necessary.

But why should we need a “virtual” reality? “Isn’t reality enough?”, one might ask. There are situations were it is dangerous, too expensive or even impossible to confront the user with reality. Think of a flight simulator where the pilots can train difficult manœuvres without being in danger. But to make the pilot behave like he would in a real plane the simulation has to be nearly perfect. This is the reason why more “natural” input and output devices are needed in Virtual Reality environments.

In the design review process we use a stereo projection system for visual output. As input devices we use the CyberGlove for navigating in the virtual environment and for gesture recognition. That means that a certain gesture can trigger a predefined event, e.g. the selection of a part. Another input device is speech recognition. This is the most natural way of interacting with a computer system.

1.2 Brief history

Volkswagen founded a research lab (the VR–Lab) in 1994 to investigate the possible benefit of Virtual Reality. After the evaluation of commercially available software products we decided to coorporate with the Fraunhofer Institute in Darmstadt and to use their software as a basis for building our own applications. A second Virtual Reality facility (the VR–Studio) was installed in 1997 for presenting design review models.

1.3 Creating a design review model

One of the first problems we encountered was to bring CAD data into the VR system for visualization. This was and still is one of the most challenging tasks. The steps to obtain a design review model can be divided into three main steps:

1. Generating a model
2. Preparing a model
3. Presenting a model

1.3.1 Generation

During this step the CAD data has to be converted from parametric surfaces to triangle meshes since common rendering hard- or software can only visualize triangles[1]. Figure 1 shows a frequently used representation of parametric surfaces. In this representation only the bounding curves of the surfaces are displayed. The density of the derived mesh can be controlled by different parameters (e.g. chordal deviation or normal deviation). A triangle mesh can be seen in figure 2. The number of polygons of the whole scene that has to be presented influences the number of frames that can be rendered within a second.

There are basically two different kinds of scenarios for virtual environments depending on the application. In a flight or driving simulator the application has to render a fixed number of frames per second (e.g. 60 or 30 fps) and the complexity of the scene (total number of polygons) has to be stripped down until it meets the desired frame rate otherwise simulator sickness could occur. In the other case the frame rate may vary because the quality of the model is more important. When presenting a design review model we usually have to deal with the latter case.

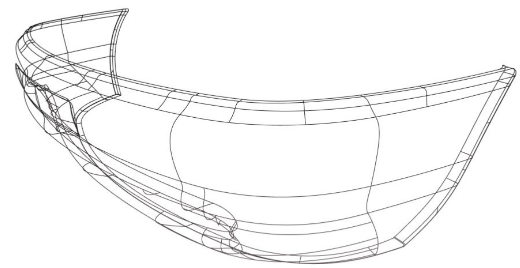

Figure 1. Diplaying the bounding curves of the parametric surfaces (Wireframe Display)

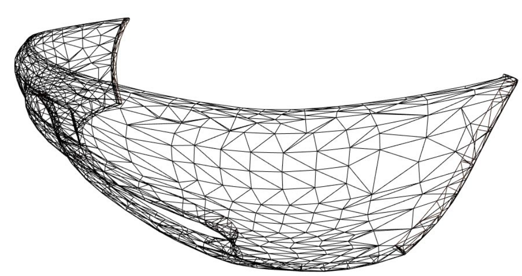

Figure 2. The triangle mesh

[1]The rendering systems can also handle quads or quad meshes, but due to the fact that each quad is internally divided into two triangles it does not make sense to distinguish between both representations.

1.3.2 Preparation

In some cases it makes sense to have a monochrome model, but usually a more realistic model is required. To achieve this goal colors and textures are used.

- **Colors:** A car company usually has predefined color palettes for exterior and interior parts. These colors have to be applied to the parts. See Figure 14 for a colored and Gouraud–shaded model.
- **Textures:** A texture is a 2D image that is displayed instead of the "real" geometry. This saves a lot of polygons and therefore improves the overall performance.

1.3.3 Presentation

In the "early days" of Virtual Reality the presentation of a model or scene was static in a sense that certain attributes (e.g. colors and textures) could not be modified or certain analytical funtions were not available.

- **Modification:** The modification of colors and textures during runtime and the corresponding user interface will be described in section 2.
- **Analysis:** The available analytical funtions will be described in section 3 and 4.

2 Evaluation and manipulation of styling concepts within a Virtual Environment

2.1 Computer Aided Styling – Requirements and possibilities

The modern product development process is particularly determined by two strategic objectives: Shorter Time–To–Market (TTM) and lower development cost. In order to achieve these goals there is a need for optimization and improvement of the entire process chain itself. Regarding an arbitrary "series process" there is a limitation in shortening it, if a distinct degree of optimization is reached. This leads to the necessity of working in parallel. "Concurrent engineering" or "simultaneous engineering" are the well–known keywords. Prerequisite of a high potential process parallelization is the early availability of CAX–data, covering every area of the entire process chain.

Since the early seventies when CAD/CAM systems were introduced, computer aided techniques improved nearly every field of research, development and construction, but not in styling. This results in a bottleneck in the corporate information flow and therefore a severe setback in the efforts of achieving the most effective workflow.

The main reason for the fact that computers are not applied in the styling phase is the lack of tools that support the intuitive and creative work of stylists, instead of forcing them to think how the machine thinks. ([3], [7], [11], [10], [5], [16]) In [7] di Giusto presents two groups of elementary requirements that have to be fullfilled, if a Computer Aided Styling System (CAS) wants to be accepted:

Creative/artistic requirements

- Intuitive
- Fast
- High quality visual images
- Flexibility
- Quick 3D verification

CAD based, industrial requirements

- Data transparency
- Painless link between systems
- Mathematical accuracy

If there were an adequate CAS sytem available, there would be a broad range of advantages. Notice that these advantages not only concern the interface between styling and engineering, or styling and top management, but also improve the work within interdisciplinary teams:

- Early access to all kinds of development data
- Simultaneous availability of information
- Less physical prototypes
- Consistent description of product data
- Possibility of early decision finding
- Easy communication of ideas, due to high–end visualization
- Believability
- Multiuse
- Comparable presentations in various contexts
- Repeatability of presentations

As mentioned above, the cardinal reason for the missing acceptance of computer aided tools in the styling studios is the lack of intuitive and creative methods and concepts for communicating with the computer. The creative energy of the stylist must not be blocked by complicated procedures of interaction. On the contrary, the ideal CAS system provides a human–computer interface which grants a direct access to the objects a stylist wants to work with, without any "technical abstraction".

Virtual Reality technology now provides such enhanced methods of human–computer interaction. There are three-dimensional displays and input devices, multi–modal communication channels and even initial solutions in giving a haptic feedback. Furthermore, VR graphic systems are usually very powerful, so the demanded quality of visualization is available. It is evident, that an appropriate VR solution for CAS could give the stylist an immersive tool that propagates the CAX integration within the styling phase.

Section 2.2 therefore presents an VR application that provides special functions for styling purposes.

2.2 Virtual Studio

2.2.1 Implementation

The Virtual Studio application *ColTex* ([8]) is based on the VR–software "VirtualDesign II" ([1]) from the Fraunhofer IGD Darmstadt, Germany and it has been developed in cooperation with the Division of Computer Graphics, University of Hanover. *ColTex* has to be thought of as a plug–in module that encapsulates the styling functions and makes use of the device drivers, rendering system and interaction handling of "VirtualDesign II" (VDII).

ColTex especially uses a cyberglove with the VDII selection mechanism, a (6 degrees of freedom) spacemouse for moving in the virtual scene, a speech recognition system that interprets the naturally spoken commands and *ColTex* also profits from the excellent visualization capabilities of VDII.

As mentioned, the Virtual Studio software is designed as a "module". All the user needs to do is to provide the information where the databases referred to are located. All performed styling modifications are logged and the results created are sent back to the database, when a session is finished or when the appropriate command is given.

One of the most important benefits is that *ColTex* renders the classical VR styling loop superfluous:

1. Assign color and material
2. Visualize
3. Think about changes
4. "Back to 1."

Within our Virtual Studio solution all those modifications are performed within the VE, restricted only by the capability of the underlying database.

2.2.2 Features

- Threedimensional controls
- Naturally spoken commands
- Individual selection by virtual pointing device
- Hierarchical selection
- Cut, copy, paste, undo and redo functionality
- Collaborative sessions
- Free manipulation of each color and material parameter, including textures
- Predefined material palettes

2.2.3 Example Session

This section presents an example session with the *ColTex* system, performed on a virtual model of a Volkswagen Sharan MPV.

Before any modification operation is done, the user has to select the part(s) he wants to work with. Figures 3, 4 and 5 show the different ways of selection. Furthermore, there are different "modes of modification". Styling operation can be perfomed on the entire material or even on the given texture, or color.

Figure 3. Selection of a single geometry

Figures 6 and 7 present the use of the threedimensional controls mentioned beforehand. A selection in the rgb–color space is done by choosing the required color in a virtual representation of the color space by hand movement. Additionally, figure 7 shows a reference sphere which helps decide what the selected material will look like.

Figure 4. Selection of the whole component

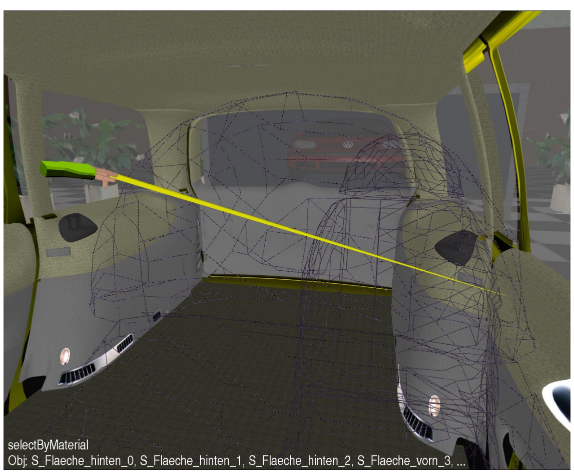

Figure 5. Selection of all components with the same material

Figure 6. 3D color cube

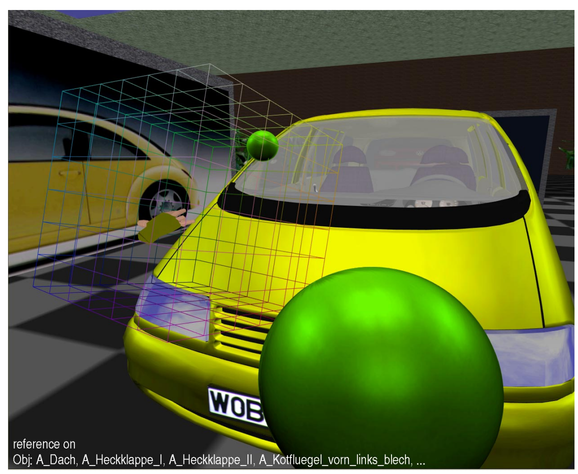

Figure 7. Color selection with reference sphere

Figure 8 shows the use of the "transparency slider" and figure 9 demonstrates the use of predefined material palettes. Again, the user performs the selection merely by moving the hand.

Figure 8. Another 3D control: A slider adjusting transparency

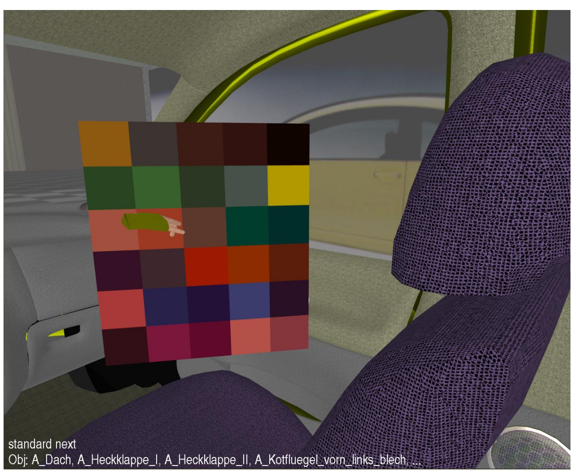

Figure 9. Color selection with predefined palette

Finally, the following two figures document an operation with textures. A new surface structure is given to the dashboard.

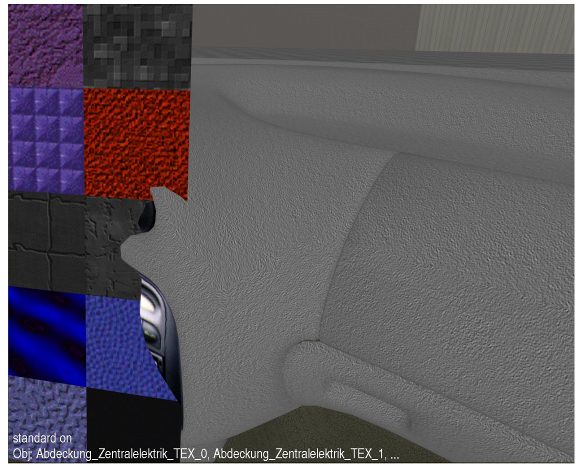

Figure 10. Different surface structures on a palette

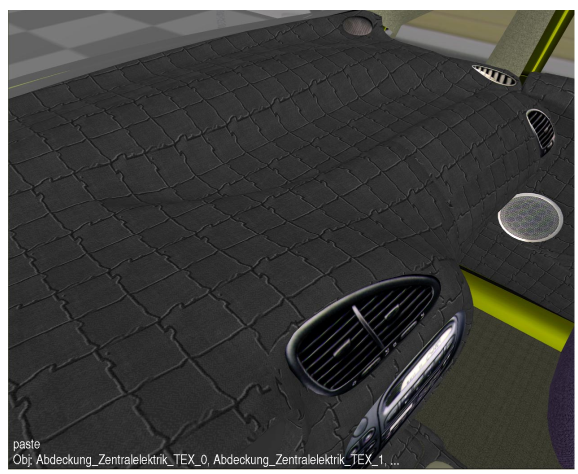

Figure 11. Dashboard with new surface structure

2.3 Gaps – An indicator of quality

Another use of Virtual Reality at Volkswagen is the evaluation of gaps and their run between different components. Apart from such evaluations only concerning the inspection of the existing CAD data, the goal of this application is the visualization of manufacturing tolerances or assembly tolerances.

Imagine there is a new (automatic) method of assembling two parts of a car interior. This new method is much cheaper than the actual procedure, but it means manufacturing tolerances in the range of 1mm.

In these and similiar cases Virtual Reality helps decide, whether such new methods are usable or not. The executed evaluations are repeatable, exact and, of course, based on the original CAD data.

Our system only allows semi automatic translatoric and rotational inspections at the moment, but it is planned to provide more complex kinematics.

Figure 12. RAMSIS in a VW Sharan

3 Integration of the the 3D human model RAMSIS

Volkswagen uses the 3D human model RAMSIS[2] for package tasks and the evaluation of ergonomical matters in new cars. Therefore we created an interface to an already existing tool for obtaining realistic CAD models of human beings. RAMSIS was initiated by the Association of the German Automotive Industry (VDA) as a joint venture of several German car companies and two seat manufacturers.

3.1 Visualizing anthropometric reliable humans

One of the features implemented was the visualization of previously generated postures of manikins. In this case the RAMSIS-VR module acts as a postprocessing tool. Different “virtual humans” can be placed into the car and it can be investigated e.g. whether there is enough space left between the head and the interior roof.

3.2 Sight analysis

Another feature is sight analysis. Since the user in a VE is able to choose every point of view he desires, it was a logical consequence to supply realistic positions that conform with known percentiles. It is necessary to know whether certain car geometries obstruct the drivers view (e.g. the steering wheel might block the view of relevant instruments).

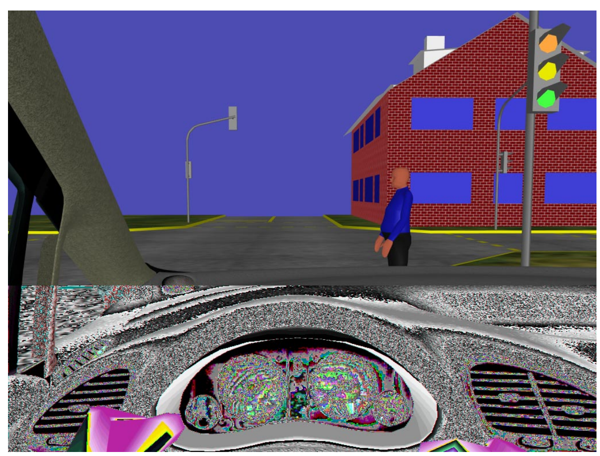

Figure 13. Looking through the eyes of RAMSIS (95% male)

[2]RAMSIS is a registered trademark of TECMATH GmbH, Kaiserslautern, Germany. For more information see http://www.tecmath.de .

4 Integration of the CAD geometry kernel ACIS

The necessary steps to obtain a Virtual Reality model from CAD data have been described earlier. When using this approach the parametric surfaces are lost or are unavailable during the runtime of the the model presentation. Our idea was to additionally load the parametric surfaces to allow analytical functions that can only be obtained by using the parametric decriptions of the surfaces of the underlying model. To achieve this goal we integrated the CAD geometry kernel ACIS[3] into our VR system. This means that the full potential of CAD systems is available in a VR system. In the following sections we will describe which functions have been integrated. As interior parts are usually very complex, we have decided to present a simpler CAD geometry for demonstrating the different features (VW Sharan).

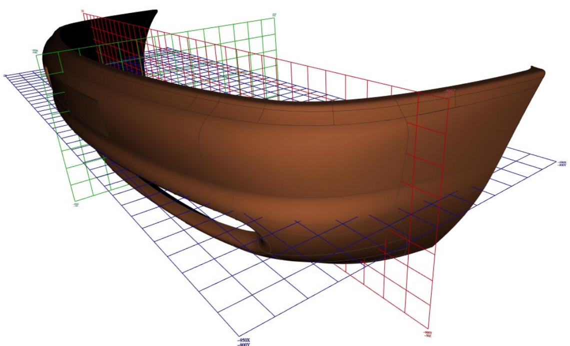

Figure 14. Complete representation of the model, additional grids and bounding curves

4.1 Creation of slices

One of the features that is often required by stylists is to further investigate the geometry by using slices. A slice is the intersection of the model with a defined plane. The result is a curve that lies within the cutting plane and therefore is two-dimensional. This is a frequently used feature of todays CAD systems and gives the stylists additional visual information of spatial relations. The task was to create a user interface for defining and manipulating the cutting planes and to visualize the slices created. Because of the fact that a slice always lies within the existing geometry it

Figure 15. Displaying slices

is necessary to manipulate the geometry as well. We can "fade" the existing geometry and thus reveal the slices. It was necessary to give the user feedback on the coordinates the current cutting plane has. This is done by displaying the coordinate points at all four corners of the cutting plane as 3D text info. The 3D text is implemented as a "billboard".

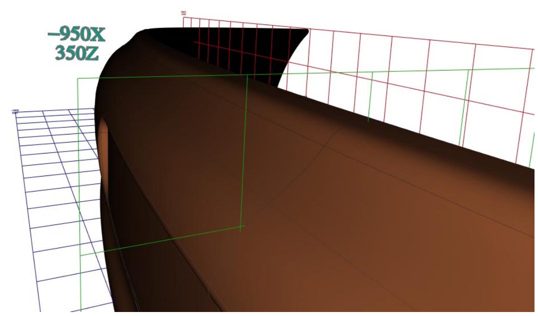

Figure 16. Billboard text

That means that this geometry is always facing towards the viewpoint of the user. This feature makes the text readable from all positions. We realized that it is essential to have the text displayed in 3D; if the text is "flat" it is disturbing to have 2D and 3D objects mixed in a virtual environment.

4.2 Visualization of bounding curves (wireframe display)

Information which is lost during the creation of a tesselated model are the bounding curves of the parametric surfaces.

[3]ACIS is a registered trademark of Spatial Technology Inc., Boulder, Colorado. For more information see http://www.spatial.com .

Bounding curves are needed to create a “wireframe” model the . They can easily be obtained using our approach. Figure 1 shows a wireframe display of a CAD model.

5 Conclusion and a look into the future

The application that has been presented in this paper shows the huge potential of VR techniques that can be used to improve the product development process. Some of these techniques are already available (and in fact are in use) some of them still need improvement. It is essential to automatize the generation of Virtual Reality models. This step is still time-consuming but will hopefully be integrated in future versions of CAD systems.

It is always difficult to look into the future, but concerning our special interest we will venture to do it:

One might say that we now have the “end of the beginning” of Virtual Reality. Many functional features up to now only provided by VR systems are more and more implemented within classical CAD or CAE solutions. A closer integration of VR based procedures into common process chains will make it easier to obtain automatisms. Many preparatory steps, nescessary at the present, will become superfluous.

But there are also some aspects, which are important, but unresolved. For example, if a user wants to have a highly immersive contact with the VE, he uses many VR devices, such as Head–Mounted–Display, Cyberglove and several tracking receivers. If VR technology does not want to be “strangled”, cordless devices have to be provided.

Another field which obviously needs further research belongs to all kinds of haptic displays. Present solutions are very specific, costly and only grant a minimum realistic impression of tactile sensation.

Techniques inspired by VR have become serious and will be an integral part of the development process in the near future.

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