Beyond Academic Exercises - Strategies Towards a Profitable Implementation of VR Technology in Company Work Processes

Thomas Reuding

BMW AG, Entwicklung Karosserie, D-80788 München, Germany
thomas.reuding@bmw.de

Abstract. Over the last years virtual reality technology has reached a level of maturity that allows us to integrate it into the primary value chains of industrial work processes. This paper describes the experiences we have had with virtual environments, specifically a four sided CAVE, at BMW. By looking at the use of this technology in car body development and engineering we will try to put initial expectations and day-to-day experience in perspective as well as bring new aspects into the discussion.

1 Introduction

Virtual reality and virtual environments have a dual character: they can be seen as media as well as tools. Over the last few years these instruments have reached a level of maturity that allows us to integrate them, at least partially, into the primary value chains of industrial work processes. This is bound to induce structural changes in work organization. However, technological rationale alone cannot efficiently master the changes in processes which rely heavily on information technology and which are characterized by a high degree of complexity. New views and strategies are needed.

Perhaps the best way to find a starting point for introducing the subject of this paper would be to look back at the different phases the technology went through in the past. Where we stand today may be more soberly assessed by remembering the hype and glamour associated with VR and putting them into perspective with its promises and potential. As with many other new technology starts, VR can be seen as having gone through the following stages:

- In the beginning there was an idea and its prophets. A community of believers and sceptics developed.
- The first followers started exploring the new technology‘s potential. Most of them drew a very euphoric picture of the future.
- The industry started to recognize the potential value of the innovation. The first few, nonetheless amazing, applications appear testing the market.
- Public opinion develops, various interest groups are searching for possible ways to exploit the subject.

- Potential users are following the technology with religious belief. Unfulfillable expectations are being raised.
- Potential technology victims emerge, proclaiming hazards for their socio-economic environment.
- An increasing number of successful applications appear. But they also show the existing limitations of the technology which brings more objectivity to the discussion.
- As the rage of application broadens, further investments, qualification and training strategies become necessary. A sense of reality is setting in.

Some, or maybe all, of these descriptions resemble the experiences of researchers and industry personnel in the field today. Thus, the discussion among them is quite heterogeneous. Perhaps this is one of the reasons why research in the field of virtual reality and virtual environments is scattered into many directions and few general approaches exist.

Even the term virtual reality is still very ambiguously defined. It often summarizes such different technologies as 3D computer graphics and stereoscopic projection systems all the way to digital mock-up methods. For the sake of clarity in this paper we will define VR as the *simultaneous* existence of:

- stereoscopic 3D computer graphics
- system performance at interactive rates
- immersive displays

This paper describes the experiences we have had with virtual reality technology at BMW. We will look at the use of a four sided CAVE [5], 2,50m x 2,50m x 2,50m in size and driven by a Silicon Graphics Onyx2 computer with 2 IR graphic pipes and 8 cpu. We operate a Ascension Motion Star Tracking System and a customized version of Fraunhofer IAO's software *Lightning* [1] with two flying joystick type I/O devices. By looking at the use of this technology in car body development we will try to put initial expectations and day-to-day experience in perspective as well as bring new aspects into the discussion.

2 Promises and Potential

The attempt to shorten product development times while increasing the quality of work and information and subsequently the quality of the product calls for the necessity to increase the quality of the decision making processes and to find ways to evaluate design options at times in which the underlying solutions have not, or not completely been proven. Virtual reality as a communications media for interdisciplinary applications promises to contribute to a significant increase in conceptual decision making stability for customer relevant product innovations.

These expectations are based on the fact that users of a immersive, virtual environment are operating a more natural man-machine interface thereby getting very effective access to computer generated data and are able to manipulate this data in a direct and natural fashion. The work of several academic and industrial researchers have supported this with some impressive results [6], [8], [9], [10], [11], [12], [13].

Nevertheless it has to be recognized that despite many international research activities very few projects rise beyond the level of academic exercises in a laboratory and gain enough maturity for a profitable implementation in companies' primary value chains and work processes.

The obvious question is: Why ?

3 Deficits in Company Practice

In daily practice at BMW the CAVE is primarily used for integrated design reviews in car body engineering when spatial presence of a digital model is important. In the sense of a styling oriented digital preassembly we create virtual mock ups with the intention to perform configuration studies, evaluate tooling and manufacturing aspects or perform access verifications and their interdependence to exterior and interior shape design. Since most engineering problems have more than one solution to a given problem, the key is to illustrate the „solution space", i.e. a set of solutions. The CAVE together with a set of virtual tools provide the communications platform to achieve this. The virtual tools allow the following main tasks:

- Move objects, make visible/invisible
- Set and move light sources, adjust light intensity
- Measure distances
- Apply markers to objects

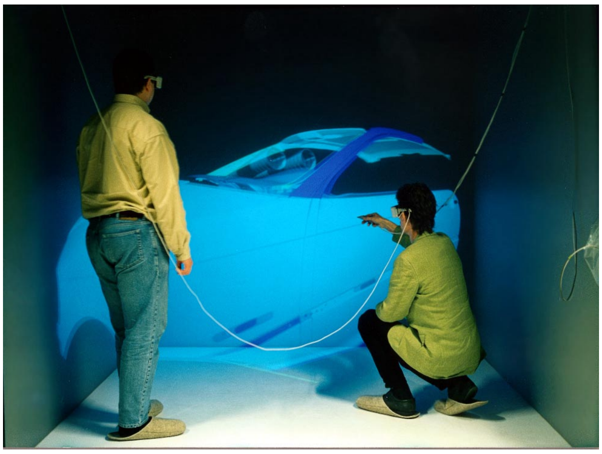

Fig. 1. Discussing design options in a CAVE

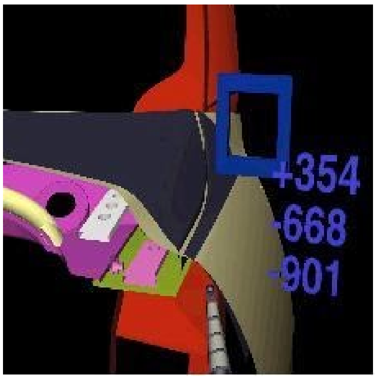

Fig. 2. Space allocation verification

Apart from the well known technical limitations with respect to projection quality or latency of system components we can identify two major obstacles for practical use.

1. The precise manipulation of virtual objects is very difficult.
The CAVE is an immersive multisided projection system with viewpoint dependent image generation (almost) in real time but there is no haptic feedback when interacting with virtual objects and 3D-positioning is severely hampered by inaccurate tracking devices. CyberGloves may allow the user to use his or her natural hand as an interaction device provided that the objects are in reach, otherwise we find ourselves awkwardly trying to manipulate objects that dangle from the end of a fishing pole. In short: rough manipulations are possible but precision interaction is not very well supported.

2. A homogeneous framework for interaction metaphors in virtual environments, similar to those of a conventional 2D desktop is missing.
The dilemma is that the 2D desktop metaphor fails once the user is <u>part</u> of the user interface. In virtual space all control and steering instruments must be present together with the user in the environment.

These two points may be crucial but they do not offer sufficient explanation for the apparent difficulties of integrating VR technology in company work processes. The following 5 theses try to illuminate the problems beyond the well known technical arguments.

<u>Thesis 1:</u> *VR systems are intimidating and make the user feel he or she is trapped and dominated by the machine. This can easily cloud any perception of the system's usefulness.*
The reason for this can easily be understood when looking at today's system components. The user is often heavily wired and thereby feels that he/she is interacting with hardware components rather than with virtual objects in a virtual world. Furthermore we lack attractively presented VR operating systems similar to the masking of computer OS commands by context sensitive graphical objects (Windows, MacOS, Irix Desktop).

Thesis 2: Virtual reality should enhance and complement physical reality rather than compete with it. Virtual environments should open up experiences and opportunities for the user that do not exist in real life.
For a moment let's view development work as the freedom to move in a crystallization process of ideas. We find three main states:

- Initial design and conceptual phase => Large design freedom (gaseous state)
- Basic proof of feasibility phase => Restricted design freedom (liquid state)
- Suitability for production phase => Almost no design freedom (solid state)

It becomes apparent how important it is to be able to hold on to validated or semi-mature partial solutions and superimpose them with new design alternatives [7]. VR technology's biggest asset is the power to utilize and operate on data of mixed maturity and to generate spatial presence for phenomena that do not have a visible character in physical reality (i.e. sound waves, electromagnetism, force fields).

Thesis 3: VR system- and user interface functions can be designed in a fairly simple and straightforward fashion if one implicitly presupposes the experience-based knowledge of the user.
Experience-based knowledge is defined as a form of tacit knowledge gained through practice and routine from working in highly networked process chains. Our user studies have shown that the presentation of virtual objects in a form tailored to the task at hand along with a selected set of virtual tools is sufficient to recall the users' experience from the corresponding real world situation and use this knowledge to interpret the virtual world. We have learned for instance, that many aspects of manufacturability can be discussed at astounding depth, given a realistic representation in a virtual environment.

Thesis 4: Successful application of a VR system is directly dependent on its acceptance by the users. This again is closely linked to a successful adaptation of the user interface to the spectrum of tasks to be performed in the virtual environment. (Spatial Interaction Toolkit)
Apart from the basic demand to make maximum use of the rendering power of the graphics computer, user interface design is the main criterion to compare VR systems. The difference between work on conventional 2D computer desktops and work in virtual space is comparable to a craftsman at his workbench and a rigger at a large construction site who has to carry his set of tools with him at all times. The latter will try to carry as few tools as possible, however, the ones chosen should be versatile and optimally suited for the tasks.

Thesis 5: Performing work in virtual environments requires a large amount of discipline and planning with regard to preparation and decision making.
Conventional CAD methods are often luring the user into making undifferentiated use of the functions the systems offer, which ultimately leads to inefficiency. Analogous to work practice in model shops where the need for good planning due to the limited resources (material, tools and manpower) is obvious: VR-based project meetings need similar preparation to be successful. Specifically one should know: What is the main topic of discussion ? What needs to be decided ? Which properties or attributes are

relevant to the decision making process and are they being presented in the virtual environment in an appropriate fashion ? How many people are participating ?

4 Strategies for Work Organization and Technical Development

Research by industrial sociologists [2] has shown that the increase of computer based technologies creates new problems and conflicts in the immediate work environment. They can be avoided or at least minimized if the practical significance of experience-based work is retained and systematically taken into account. This calls for a dynamic role definition between human resources and technology in the sense that personnel is to a large extent free to choose from technological as well as organizational options based on what they see is the most appropriate for their tasks. Therefore we need models for work organization and skill development to support the options that technology provides.

Due to the nature of research and development work processes in which successful solutions are often achieved in an iterative fashion, communication is the key to success. It is therefore necessary to retain the mechanisms of intra personal cooperative work despite the fact that conventional computer driven technical systems have a tendency to create spatial distance (people work at different locations and share only data) and do not allow the common experience of physically working together and exchanging ideas face to face.

In light of this, BMW has established a semi-closed work environment the size of about 750 square meters within its research and development facilities in Munich. It makes it possible to bring together personnel from style design, engineering, tooling and manufacturing planning as well as the model shop in a flexible way (Fig. 3).

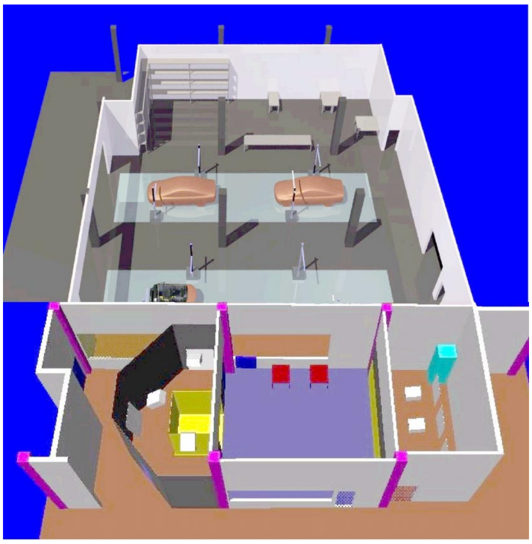

Fig. 3. Concurrent design work environment

The area is divided into various open zones for shape design and hand crafted model generation for vehicle interiors and exteriors, complete with 3D data acquisition systems. Next to this, a zone focusing on digital and virtual technologies is supposed to complement the physical world. Here, conventional CAD screens and high performance visualization systems are installed. The latter comprise a rear projection wall, 6,40m x 2,00m in size (PowerWall) to be used for displaying the vehicle in full size, proportionally correct, in photorealistic quality for design reviews, and a four-sided CAVE. Work in the CAVE focuses on topics where spatial presence of the geometry is important and the interdependece between shape design and manufacturability is evaluated (Fig.4 and 5). Figure 4 shows the examination of a sheet metal part together with results of numerical simulation of the stamping process. The distribution of the material's thickness is color coded and mapped onto the surface of the part. Also, note the use of the virtual measuring tape, the 3D marker and the virtual laser-pointer to accentuate the area of interest.

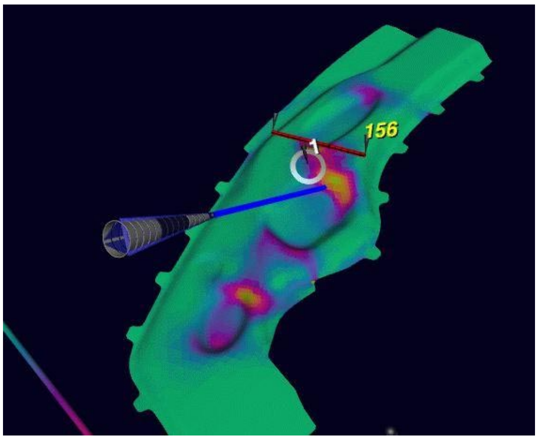

Fig. 4. Analyzing a stamping simulation

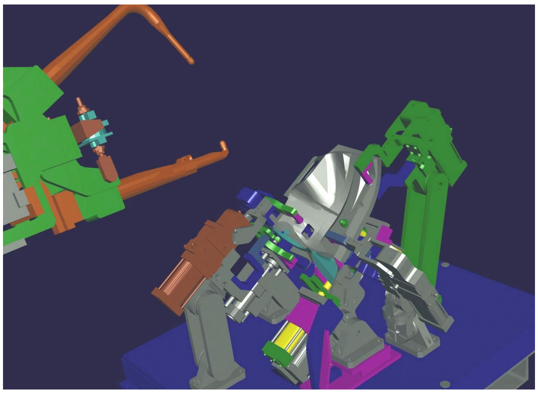

Fig. 5. Virtual welding station

The technical infrastructure of the work environment is designed to support collaborative engineering by making engineering and manufacturability issues presentable while the interior and exterior design of the vehicle is still evolving. Spontaneous face-to-face communication between personnel is possible along with a relatively free choice of media (real models vs. virtual models). This is crucial in order to build confidence in virtual environments. Providing established tools and media (i.e. real models) along with their virtual counterparts eases the apprehension when decisions have to be based on virtual models and it initiates and promotes a learning process towards believing in „what-you-see-is-what-you-get“.

In the area of technical development we see the priorities in concepts for application specific user interfaces, configurable sets of virtual tools, wireless interaction hardware and in coupling real time graphics and virtual environments with high performance computing in structural and fluid mechanics. Recalling thesis number 2 we do not believe in simply trying to recreate forms of interaction in a virtual world that exist (infinitely more powerful) in the real world. What we need is an intelligent use of those human sensors that work best in VEs: Seeing and hearing. Acoustic diagrams and tools for acoustic exploration of 3D space for instance are quite useful and provide three potential means of transmitting information: frequency, amplitude and modulation.

Our currently available interaction metaphor (Spatial Interaction Toolkit), although sufficient for the moment, need to be enhanced in the future. Especially the demand for mixed environments in which real and virtual objects coexist (Fig. 6) and the subsequent need for calibration is inadequately met.

Fig. 6. Mixed mockup of a vehicle’s interior

It also appears to be useful to integrate wireless voice input or I/O devices which conventionally exist outside of virtual environments into a new approach towards 3D user interfaces in virtual worlds. This would address the field of wearable computers or components which several researchers are working on.

5 Acknowledgements

Many people and colleagues have made valuable contributions to the successful implementation of VR technology in BMW work processes. Special mention is due to Martin Schulz (University of Stuttgart), Dr. Sven Kuschfeld (BMW), Andreas Weber (Rover Group), Wolfram Wameser (BMW Sparte Presswerk), Dr. Wolf Bartelheimer (BMW), Dirk Reiners (Fraunhofer IGD, Darmstadt) and Andreas Simon (GMD, Sankt Augustin, formerly Fraunhofer IAO, Stuttgart). Many thanks also to Robert Bauer and the visualization group at EK-30 as well as Pamela Meil and her colleagues at Institut für Sozialwissenschaftliche Forschung, München, for insightful discussions on industrial sociology.

References

1. Blach, R., Landauer, J., Rösch, A., Simon, A., A Flexible Prototyping Tool for 3D Real-Time User-Interaction, Proc. Virtual Environments ’98, Springer Verlag, Wien, 1998
2. Böhle, F., Rose, H., Technik und Erfahrung, Arbeit in hochautomatisierten Systemen, Institut für Sozialwissenschaftliche Forschung (ISF), München, Campus Verlag, 1992
3. Boritz, J., Kellogg, S., A Study of Interactive 6 DOF Docking in a Computerised Virtual Environment, Proc. IEEE Virtual Reality Ann. Int’l Symp. (VRAIS 98), IEEE Computer Society Press, Los Alamitos, Calif., 1998
4. Bryson, S., Approaches to the Successful Design and Implementation of VR Applications, ACM Siggraph’94, Course Notes, 1994
5. Cruz-Neira, C., Sandin, D., J., DeFanti, T.,A., Surround-screen projection-based virtual reality: The design and implementation of the CAVE, Proc. ACM Siggraph’93, ACM Press, New York, 1993
6. Dai, F., et al., Virtual Prototyping Examples for Automotive Industries, Proc. Virtual Reality World ’96, Stuttgart 1996
7. Ferguson, E.,S., Engineering and the Mind’s Eye, MIT Press, Cambridge, Mass., 1993
8. http://www.mercedes-benz.com/fairs/d/messen/iaa97/iaa_pr10.htm
9. Kindratenko, V., Kirsch, B., Sharing virtual environments over a transatlantic ATM network in support of distant collaboration in vehicle design, Proc. Virtual Environments ‘98, Springer Verlag, Wien, 1998
10. Rantzau, D., Rühle, R., Analyzing the Thermal Comfort in a Car Cabin Using a Modular Virtual Prototyping Environment, Proc. 31st ISATA Conference, June 1997
11. Reuding, Th., Schulz, M., Virtual Reality and the Link between Design and Engineering Analysis, Proc. Virtual Environments ‘98, Springer Verlag, Wien, 1998
12. Riedel, O., Breining, R., Scharm, H., How to use Virtual Environments for Engineering Projects, Proc. ACM Siggraph’97, ACM Press, New York, 1997
13. Schulz, M., Reuding, Th., Ertl, Th., Analyzing Engineering Simulations in a Virtual Environment, IEEE Computer Graphics & Applications, Vol.18, Nr.6, November 1998