Digital Material

Perception, Interaction and Immersion in Virtual Environments

Marco Hemmerling[1]
Detmold School of Architecture and Interior Design
[1]Hochschule Ostwestfalen-Lippe – University of Applied Sciences
Emilienstrasse 45
D-32756 Detmold
Germany
marco.hemmerling@hs-owl.de

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Abstract: This paper outlines two major aspects of virtual environments for architectural design. On the one hand it focusses on how to use virtual reality as an extended tool to generate spatial design by building up and interacting with a three-dimensional digital model. On the other hand it describes - based on a case study - the relation between perception, interaction and immersion in virtual environments. Both approaches can be interconnected to a continues design process, that allows the designer to create, manipulate, visualize and decide on spatial concepts in a holistic three-dimensional simulation.

1. DIGITAL ARCHITECTURAL DESIGN

1.1 Introduction

The connection of architecture and computer science generates manifold possibilities for the development of new products and services. The computer is certainly the most comprehensive and dynamic medium ever available to architects for developing and realising spatial concepts. Exploiting this potential requires the ability to use the computer as an interactive instrument and use its artificial intelligence as an expansion of

possibilities. Developments over the past 20 years in computer aided architectural design and production show the steadily growing influence of digital media on the work of architects. Processes for developing architectural concepts and formal designs, and even the way architecture is perceived, have evolved considerably through the implementation of computer technology.

1.2 Virtual Reality in Architecture

Architecture and interior design are ideal fields of application for Virtual Environments. Every plan, every perspective tries to generate a comprehensive spatial statement with the easiest means. Indeed, not everybody understands the language of the two- and three-dimensional abstraction enough to be able to experience and judge new designs and projects on this base. Even less the complex relation between form, material and light are displayed in such forms of representation. In this respect an interactive virtual model which takes into consideration all these aspects in an integrated spatial context is an important medium for the development and communication of architecture and interior design.

The design can be examined, valued and developed in an extended way through the interaction with the 3D-model in real time. At the same time spatial concepts, materialisation, light situations and proportions can be experienced in an integral scenario. Furthermore the virtual models allows the direct manipulation of relevant parameters, such as form, material and light, so that different spatial atmospheres can be dynamically examined and directly compared.

1.3 Human-Computer Interaction

The focus of the development of human-computer interaction in the field of Computer Aided Architectural Design (CAAD) lies in the investigation and implementation of a more intuitive and direct communication within the design-process. We perceive the physical world spatially, the virtual 3D-model however appears only two-dimensionally on a flat screen. Conceptual models in the work routine are indispensable, in order to maintain the feeling for the physical world. They make the abstract entity "architecture" a little bit more tangible and comprehensible and help at the same time to formulate it more precisely for the designer and other people involved in the design-process. Larger and/or more complex projects cannot yet be realised three-dimensionally in the desired size, speed, quality, quantity and cost-frame. The underlying questions in this context concern two major aspects of human-computer interaction:

1. How can the intermediate steps in the design process of the virtual working models be displayed spatially?
2. What kind of interface-devices - beside the two-dimensional mouse navigation - can generate and modify 3D-models within the design process?

The overlap of virtual environments and reality creates a mixed reality or so called augmented reality with different stages of immersion. The analysis of available technology contains on the one hand manual input devices with several degrees of freedom and on the other hand visual output devices with various solutions for stereoscopic perception. Within the case study “Digital Material” several interactive human-computer interfaces were investigated in relation to their benefit for an intuitive, direct and comprehensive use in the field of architectural design.

1.4 Stereoscopic Projection

Spatial vision is based on the binocular system. The fact that the vision-conus of both eyes penetrates itself partially and secondly the eye-muscles are fixing the objects accordingly enable the stereoscopic perception of space. Both two-dimensional retinal image (parallax) - slightly varying by the distance of the eyes - are combined neurally to an overall image of the three-dimensional world. The process of spatial perception is based on three aspects:

1. The real environment - including its objects - is three-dimensional perceived;
2. a two-dimensional image emerges on the retina ("retinal image");
3. from this two-dimensional image a three-dimensional impression is generated.

A three-dimensional impression can also be evoked, by an artificial spatial representation of an object or space, e.g. a perspective design. Objects presented by two-dimensional images are interpreted spatially if they fulfil a sufficient degree of depth criteria. A drawing or an illustration, which is in its functions adapted to stereoscopic vision, is called stereogram or -copy. It is composed from two stereoscopic half-images, whose deviations correspond with the parallax of monocular retinal images. polarised 3D-glasses create the illusion of three-dimensional images by restricting the light that reaches each eye an example of stereoscopy to present a stereoscopic scene, two images are projected superimposed onto the same screen through orthogonal polarised filters. The viewer wears

eyeglasses which also contain a pair of orthogonal polarizing filters. As each filter only passes light which is similarly polarized, each eye only sees one of the images, so that the three-dimensional effect is achieved.

Figure 1. Powerwall with reverse projection technique at the Detmold School of Architecture and Interior Design

2. CASE STUDY

2.1 Digital Material

Within the scope of the project "Digital Material" at the *Detmold School of Architecture and Interior Design (University of Applied Sciences)* different forms of digital representation were examined with the help of various software applications (Quest3D, 3D-Studio-Max, Cinema4D, Rhinoceros) concerning their possibilities for the visualisation of material qualities in pre-defined spatial typologies (hotel room, patient's room, bar and hotel lobby). Besides the three-dimensional representation on a flat screen (rendering) the different designs were also presented through a three-dimensional, stereoscopic projection on a Powerwall. The focus of the research in this context concerned the human perception of virtual spaces. In addition to spatial geometry, aspects of material effects, light ambiance and movement through space in real-time were examined.

The third-party fund-project was supported by *Thermopal* - a manufacturer of decorative laminates for interior design and furniture. The aim for a future collaboration is the realisation of a specific virtual environment. On the basis of a three-dimensional, stereoscopic projection

the architect and interior designer will then be enabled to make design decisions by comparing and evaluating different spatial atmospheres in real-time.

2.2 Digital Visualisation of Material Properties

Materials in general are characterised by different properties and levels of perception. Besides the visual appearance like colour, texture an light ambiance, aspects of tactile, olfactory and acoustic features determine the property and perception of a certain material. Visualisation software, like Cinema 4D, 3D-Studio-Max or Maya, is able to simulate the visual appearance of materials by using an image of a real material – the texture - as a base for further manipulation. In combination with effects like bump, transparency, reflection, refraction, glossiness, diffusion or illumination the digital material appears real and implies, next to the visual perception, as well aspects of tactile, olfactory and acoustic properties.

Furthermore the realistic appearance of a material in a digital rendering is depending on the the mapping – the way the generated material is applied to a certain geometry. Thirdly the most crucial and as well most difficult setting is the calibration of the light ambiance in the virtual scene. The use of an appropriate rendering engine rounds off the set-up for a photo-realistic rendering.

Within the project “Digital Material” different combinations of material settings, mapping techniques, light sources and rendering engines such as Scanline Renderer, Mental Ray and V-Ray where examined on an interior design with 3D-Studio-Max. The inter-coordinated use of daylight systems and/or photometric lights in combination with the internal Mental-Ray render engine and the Arch & Design material editor delivered the best results for a realistic material representation.

After the generation of a high-resolution rendering the material designs were rendered to texture and then exported via the CGR-Exporter to Quest 3D for an interactive real-time simulation, that allows the manipulation of the virtual scene in terms of light ambiance and variations of the material. The results where finally presented by a stereoscopic projection on a Powerwall, using polarised 3D-glasses to generate the three-dimensional vision.

Figure 2. Visualisation of a virtual environment with daylight and artificial light ambiance.(Renderings by Felicitas Albring)

2.3 Real-Time Movement and Interaction in a Virtual Environment

An intuitive and precise navigation in the virtual scene is a relevant factor to generate a holistic feeling of immersion. Cursor, mouse, space-mouse or joystick, that are usually used to move through the digital space, are fixed to a certain position and limit the freedom of the movement. While testing different navigation tools, the *Nintendo Wii* navigator appears to be an appropriate interface in virtual environments. It allows a free movement in all three spatial dimensions and generates additionally the possibility to interact directly with the 3D-model by activating or manipulating objects in the scene. By using the same interface that is used in computer-games the feeling of immersion increased significantly.

Figure 3. Visualisation of hotel room design (left, rendering by Michael Brezina) and stereoscopic projection of the virtual 3D-model on the Powerwall (right, photo composition)

3. CONCLUSION

A virtual environment establishes a mutual simulation for the generation and evaluation of spatial design. In the design process it functions as an interactive platform that supports the generation and manipulation of a spatial idea and is at the same time able to display various parameters and different stages of the design.

Furthermore it intensifies the perception of the design. By navigating in real-time through a stereoscopic projected virtual scene - in combination with the option to interact directly with the virtual model - the contemplative feeling of immersion increases significantly compared to a two-dimensional projection of a three-dimensional model, that we know from standard architectural visualisations. In that respect the immersive perception of virtual environments contributes considerably to the evaluation and decision process on spatial design and is consequently a relevant tool for the development of architectural concepts.

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