Studying User Experience in Virtual Environments

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ABSTRACT
This publication gives an approach to the analysis of user experience (UX) with the help of virtual reality (VR). Virtual representations (virtual prototypes) can be created early with the help of digital design data and development decisions can be made in early stages of the product development process. This provides the opportunity to include internal and external users and customers in the development process and to obtain relevant knowledge about the user experience. The following study was conducted at the Technical University of Ilmenau in co-operation with an industrial company. The theoretical results are verified with the help of an empirical study. Finally, some future developments are presented.

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User experience, Virtual Reality, Product Development

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

MOTIVATION

The design of a customer product (especially technical systems) goes far beyond the pure design of functionalities. Besides e.g. safety, transportation, ecological requirements a product must have a good usability. In addition, other criteria are relevant for users which are called non-instrumental qualities according to Hassenzahl [3]. This includes aesthetic and hedonic aspects as well as pleasure and fun when using the product. In order to evaluate user experience which goes beyond functionality and usability all aspects of user interaction (and user perception) of the product have to be included [6,7]. Virtual reality can be a powerful tool for this process which is investigated and confirmed in this paper.

The early representation of future products significantly helps to shorten the time-to-market and thereby to gain competitive advantages. The high complexity of technical products can be simplified by presenting only relevant aspects in virtual models. Also the complexity of the product development process (especially when using methods like simultaneous engineering or concurrent engineering), the geographical distribution of decision makers and the internal and external communication (e.g. with suppliers or customers) can be handled more easily.

Physical prototypes, which were a common evaluation option in several industries for a long period of time, are expensive and hard to produce. They are nearly invariable so single prototypes have to be produced for every design variation even if only few changes in product data have to be visualized.

Due to their flexibility, their good costs-to-time relation and their re-usability, virtual prototypes have become popular. Not only developers or designers but also customers can make decisions with the help of virtual prototypes in order to avoid development mistakes. Customers decide free of technical constraints, process or product development thinking and they know (their) application scenarios in detail. Therefore user-typical scenarios can be easily simulated in VR (e.g. the use of the future product in a home environment). Thereby ideas about customer expectations can be empirically analysed. The inclusion of valuable user knowledge in the current product development process means a decisive advantage on the market.

For the development of technology, interaction and usability as well as optimization of the virtual product and process representation, the Competence Centre Virtual Reality (KVR) was founded at Ilmenau University of Technology. The KVR is supported by eight departments with different scientific fields of research. For studies of the applicability of VR in an industrial context, a collaboration between a company (dealing with the development and production of vacuum cleaners) and the department of media production (Fachgebiet Medienproduktion, Technische Universität Ilmenau) was established. The project is also supported by the department of engineering design (Fachgebiet Konstruktionstechnik, Technische Universität Ilmenau). During the study the company made product data and product/ production knowledge available. Also volunteers out of relevant professions at the enterprise participated in the empirical study. The KVR provided hardware and software. The hardware consisted of a flexible 3-screen-projection-system with a spatially precise and highly innovative audio system and intuitive interaction devices. The departments of media production and engineering design led the scientific research and implementation of the project.

ACTUAL SITUATION

Before implementation of the project, the cooperating company had no experience with immersive, stereoscopic, large-sized product visualization. Some simple visualizations had been realized during the product development process out of the 3D-CAD (Computer Aided Design) system.

In early stages of the development process (aesthetically-oriented) designers developed form and aesthetic aspects of the future product by means of a CAS system (Computer Aided Styling). First physical prototypes could be produced out of the design data. They helped to evaluate especially shapes and sizes but only few functional aspects. Afterwards, the resulting surfaces were converted in mathematical descriptions and producible components. This step of the process had to be finished and confirmed by producing another physical prototype with a high degree of details. It was presented in one standard colour in a neutral laboratory environment so as to get constant evaluation conditions and to be able to compare the prototype with competing products.

TASKS

It was the central task of the study was to examine if virtual reality can be used for analyzing digital product data in early stages of the product development process. The following aspects were declared most relevant: form/shapes, sizes, surface structure, colours, and materials.

According to the Usability Engineering Lifecycle [4] the study started with a requirements analysis. Therefore the following factors had to be analyzed:

- User, Task
- Technical platform, Design Guidelines

Mayhews' approach had to be extended to the analysis of the virtual object [5] – in this case the future product (a vacuum cleaner for the mass market). Since the product properties are important for the definition and description of the virtual representation, an analysis of the product has to be made. Depending on the product property to be examined it has to be defined which human senses should be stimulated with the digital representation and what requirements (visual, auditory, ...) have to be fulfilled.

The ability of the virtual environment to represent the relevant product characteristics and their evaluation possibility was to be examined in an empirical study. The obtained results had to be evaluated and the preparation process from digital product data to a VR-capable model should be formulated in a guideline.

IMPLEMENTATION

Requirement Analysis

As part of the requirement analysis we examined relevant characteristics of users and their tasks. The most important user characteristics [2, 8] are: age, sex, sensory perception specifics, cognitive processes, media competence, professional knowledge, physiology.

In our study we particularly analyzed and described the role in the company (professional knowledge) and the skills (media competence) to deal with 3D applications (e.g. 3D-CAD/CAx, computer animation software, virtual reality, ...). The following roles have been identified:

1. Aesthetic Designers
2. Engineering Design
3. Marketing, Sales
4. Management
5. Users / Customers

These roles could be divided into two target groups. Firstly there are external customers (role 5) which means users in the common sense. Secondly there are internal customers which are involved in the product development process (role 1-4). Moreover, these roles have been supplemented by a description of tasks and activities[1] in the product development process [1]. This was done by focus groups and individual interviews. Afterwards both target groups could be analyzed referring to their user experience when dealing with the (virtual) product. The missing VR experience of the target groups influenced the test design and interaction design in the developed virtual environments.

Because the use of VR had not yet been established in the cooperating company there were no guidelines for the design of human-machine interface of the virtual environment. Thus, such guidelines should be defined as a result of the user tests. The selection of hardware and software also formed part of the study.

In conjunction with the task analysis of the different users the product was analyzed and the relevant product properties were described. This was done through interviews and own studies of the product. The identified properties were mainly non-instrumental qualities such as aesthetics and joy of use. These qualities should be examined and determined in a first step based on a visual, virtual representation. Therefore the following requirements were defined:

- The visual representation must be sufficiently correspond to the future product (especially to its relevant properties)
- A photorealistic representation with a high level of detail, natural lighting and accurate light simulation is essential
- In addition, a versatile, free interaction has to be made available for precise analysis of the product
- The opportunity of switching between different product variants, equipment, model colours, lighting situations also increases the flexibility and safety of decisions

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[1] Bowman (1999) declared task context, application, input/output devices relevant for the optimization of user interfaces

Data processing and software selection

The design data (with all components) had to be converted into an editable format. We used *Autodesk 3dsMax* for the the model cleanup and the creation of virtual scenes and animations. Furthermore, materials of the product had to imitated by shaders and textures, which were also created in 3dsMax. The photorealistic environment was pre-rendered in the software with the help of lighting simulation methods like global illumination and raytracing. Real-time rendering of lights and shadows was not possible in the currently used VR software (*vrcom vd2*). In order to use the data in the VR software we finally had to convert the data into tessellated surfaces (polygon based meshes). The data format of vd2 is similar to the VRML format.

Development of virtual scenes, interaction / animation

According to the defined requirements two virtual scenarios were created. One scenario presented the product in a neutral environment without other virtual objects or a clearly recognizable room. In this scenario a lot of interactions were integrated, for example changing of material colours, lighting, automatic turning, tilting, opening or changing equipment. Therefore the corresponding animations had to be programmed. The second scenario presented the product in a home environment with a lot of typical accessories like shelves, chairs, table, pictures etc.

TEST DESIGN AND RESULTS

Development of empirical tests

The central hypothesis of the test was formulated as follows: “Virtual prototypes allow studying user experience similar to physical prototypes with identical test results”. To prove this hypothesis we extracted one important aspect of user experience: experiencing aesthetic and functional properties. Therefore these properties had to be classified into evaluable categories. We defined the following ones: size, proportions (ratio of component sizes), colour, surface structure, quality of materials, design details, overall impression.

The test was planned as a comparing study with two test groups. It based on the comparison of the prepared virtual model in two scenarios and the physical prototype. At least six volunteers were chosen out of each group (product experts / internal users and lays / external users) for the test. The experts were recruited out of the company’s departments aesthetic design, engineering design and marketing.

The lays represented possible customers, so the range of age, sex and technical knowledge was chosen similar to the normal population.

By testing experts and non-experts we could also analyze the influence of experiences with 3D software (e.g. CAD) and knowledge about product design processes.

Testing

Interactions in the virtual environment were done by one of the two test leaders due to the missing VR experience of the volunteers. The VR scenarios were introduced by some technical explanations and a little presentation of the possibilities in virtual environments. The test process based on a semi-structured questionnaire and took about 45 minutes. We recorded audio and video during the test to benefit from the statements and facial expressions of the test persons (thinking aloud method).

The test consisted of 4 phases:

1. Virtual scene: living room with test object (fully equipped vacuum cleaner)
   Objectives: accommodation to the virtual environment; estimation of sizes with the possibility of comparing with known objects (table, shelf, magazines)
2. Virtual scene: presentation / point of sale simulation with neutral, grey background
   Objectives: evaluation of design details and surface structures; estimation of proportions
3. Real scene: physical prototype in front of a neutral, grey background
   Objectives: same tests as in phase 1 and 2; comparison between virtual and real prototype, evaluation of colour perception
4. Virtual scene: presentation / point of sale simulation
   Objectives: comparison of virtual and real prototype with regard to colours; evaluation of overall impression

Test Results

The hypothesis of the empirical study could not be verified in all aspects but we determined some positive results. Sizes and proportions could be exactly estimated by experts and non-experts. The test persons therefore used known objects (virtual living room scenario) or even their fingers due to the precise stereoscopic representation of the test object.

The evaluation of colours was the biggest problem in the virtual environment. Especially the design experts criticized the non-realistic visualization of colour aspects (e.g. missing shadows or metallic lacquer effects) and the incorrect representation of colour intensity and colour saturation.

In contrast to the colour design details and surface structures can be exactly examined by both experts and lays. One exceptional case was the evaluation of the material quality of the handle, because the test persons could not experience haptic aspects.

The grading of the overall impression of the virtual prototype in comparison to the real prototype was different between experts and lays. The future customers and users of the product (lays) believed that they could evaluate the whole object very well. The experts pointed out some deficits, especially colours, so they would not use virtual prototypes in all design phases.

The qualitive analysis of the recorded video and audio material helped to support and to refine the quantitive results of the questionnaire. We also got some hints beyond the test objectives, like including virtual pointers to allow the cooperation in bigger groups, including normed objects (e.g. ruler), visualization of airstreams, integrate a fourth projection screen on the floor (especially for "ground-related" products like vacuum cleaners).

Summarizing we can state that virtual prototypes have a high potential to support the product development process. Especially early design phases could profit from quick and easy preparation of models. Using virtual prototypes in further development phases means to distinctly improve the visualization. The requirements of the visualization have to aim exactly at the demands of users – engineers as well as future customers.

CONCLUSION & OUTLOOK

In this paper we presented an approach to the evaluation of user experience in virtual environments. Getting relevant information about and from users in early stages of product development results in competitive, user-focused products. We created an empirical test to examine two target groups (internal and external users) and their needs for adequate product visualization. First guidelines for the virtual representation of relevant product properties were extracted out of the analysis.

In future we want to extend the virtual representation to acoustic properties and to integrate a physics engine to get a more realistic impression not only of aesthetic features but also of functionalities and the physical behaviour of the future product. This will allow for investigations of ergonomic aspects via interaction with the product or via simulating human avatars.

The results of our studies show that the visualization has to be improved to photorealistic rendering. Therefore we plan to co-operate with the department of computer graphics at Ilmenau University of Technology. Visual effects like raytracing, real-time shadow rendering, refraction and the correct representation of complex product materials and lighting situations shall be integrated.

Furthermore, basic virtual configurations and scenarios have to be developed. This will allow a fast integration of virtual reality into the product development process of our co-operation partner and an easy evaluation of digital design data. Typical scenarios could be: neutral, laboratory conditions (evaluation of the product or comparison with competing products), purchasing situation (e.g. consumer electronics store) or living situation (e.g. home environment).

Other useful features for studying user experience are:

- Writing notes / comments in virtual environments
- Communication functions for distributed virtual reality
- Non-immersive visualization on different devices and platforms (e.g. web-based product representation)

Last but not least there is the future perspective of direct manipulation of design data in virtual environments by easy-to-use tools and an intuitive interaction. This kind of engineering would allow the involvement of the customer into the development of future products. User experience could be evaluated and integrated in real-time.

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