

Development of a Virtual Reality Solution for End User Involvement in Interior Design

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This paper describes development and test of a prototype Virtual Reality system aimed at user involvement in hospital design. User needs and functional requirements are captured by interviews and observations in three case studies of ongoing projects in Denmark. Based on the identified requirements, a prototype is developed based on a multitouch display for manipulating room layout in a floor plan view and a set of Oculus Rift glasses for experiencing the design in Virtual Reality. Together with users from the studied cases, test scenarios were performed to identify possible benefits, challenges and further requirements to the system.

Keywords: User involvement, hospital buildings, interior design, virtual reality

INTRODUCTION

Within a period of 10 to 15 years, the Danish health sector is investing approximately 6 billion Euros in a number of new hospital buildings. During the design of these complex buildings, the design teams to a large extent use physical full-scale mock-ups to support the dialogue with end users of different professions. This approach enables users to provide valuable input for the design of future working environment, logistical issues, discuss various solutions and testing them through role playing. Involving users in this way is important for the final solutions, but the preparation of physical mock-ups can be costly and it will be difficult to reach very many design alternatives with physical mock-ups, both due to cost of the mock-ups and the time it takes to dismantle and set up new mock-ups. Additionally, it will be difficult to physically create major sections, of the future building to study navigation and logistic aspects, since the physical facilities that are available for user involvement imposes restrictions on the size of these (Leicht

et al. 2010). However, many resources are spent on building and rebuilding physical mock-ups as well as transporting users to the mock-ups, performing tests of future working routines, evaluating, reporting at redesigning the architects' design proposals.

The use of virtual mock-ups has the potential to support a number of the issues identified with physical mock-ups. Previously, technologies like Virtual Reality have been associated with high costs for both hardware and software, but recent year's development has lowered these costs drastically. It is now possible to buy well-functioning virtual reality glasses at very affordable prices. This makes it interesting to look for ways to support and expand the existing working methods and processes with new technological initiatives. For example, the use of virtual mock-ups could provide new opportunities to experience and try out more test scenarios, and also to simulate and analyze situations than with physical mock-ups. (Johansson, 2012; Leicht et al. 2010; Peavey et al. 2012).

The idea behind the current project is to investigate the possibilities to partly replace physical mock-ups with Virtual Reality mock-ups based on the designers' 3D models. Based on a close collaboration with a number of ongoing healthcare projects, this paper examines how Virtual Reality can support user involvement through the creation of virtual mock-ups, using building models from the consultants existing BIM-environment.

METHOD

Based on system development methods from Contextual Design (Beyer et al. 1998) a prototype of a Virtual Reality system to facilitate the creation and use of virtual mock-ups is developed and tested. The work is based on three case studies, where observations of current work practices, as well as interviews result in a needs assessment in relation to the work associated with mock-ups in 3 temporally dispersed stages. This gave an understanding of the existing working processes and needs of the involved actors prior to developing and testing the prototype system. In addition it gave valuable input to identify future user scenarios of actual work associated with mock-ups and the use of mock-ups after trials are completed.

CASE STUDIES

Three ongoing projects in the healthcare sector were chosen as case studies. The selected cases were chosen to cover different aspects of user involvement and different ways to support user involvement in different stages of the design process.

Case 1 was Department for Trauma and Torture Survivors located in Vejle, Denmark. This case focused on user involvement in the early design stage before any kind of mock-ups were built. During brain storm sessions, the users should think out and describe future working routines which should lead to descriptions of requirements for the facilities including e.g. requirements to room affinities. 15 employees in 3 groups should describe the expected 'patient travel' through the new facilities mainly by means of coloured post-its. No floor plans or other graphic illustrations of the planned facilities were used at this

stage, so ideas regarding geometric aspects of the new facility were only exchanged verbally.

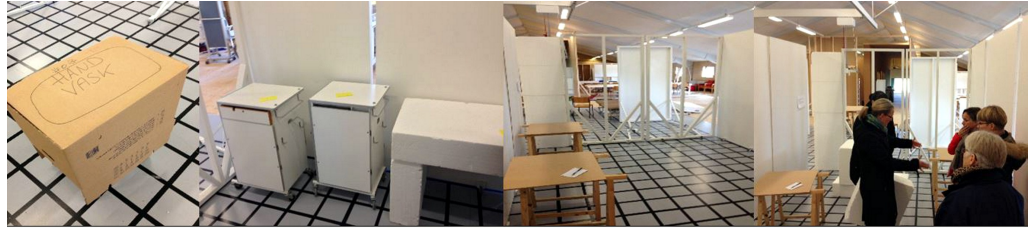
Case 2 was part of a new hospital in Gødstrup, Denmark. This case focused on user involvement in the planning of layout of new medicine rooms. Physical mock-ups of design proposals were built in test facilities near the construction site and users should test and find the best solutions for future working routines and collaboration in the full scale mock-ups. Room boundaries were created by partition screens as shown in figure 1 and equipment was represented by more or less abstract artefacts made of different materials. Figure 2 shows examples of artefacts e.g. polystyrene sheets representing a Laminar Airflow Bench and a group of users in the full scale mock-up. The users furnished the room with the artefacts to study possible future working routines. Facilitators supported the discussions and brought additional artefacts as requested by the users during the session. During these exercises the users found it necessary to start sketching floor plans of the room indicating position of equipment to complement the full scale mock-up and to keep track of discussed design alternatives as well as comments explaining design decisions.



Figure 1
Room boundaries
of full scale
mock-up were
created by partition
screens.

Case 3 was a new university hospital in Aarhus, Denmark. In this case a role play preparing users to work in the new facilities was studied. Scale models of the planned facilities were represented by large prints of floor plans combined with Lego scale mod-

Figure 2
Users discussing
furnishing and
examples of
artefacts
representing
different types of
equipment.



els of equipment, patients and personnel. Figure 3 shows an example of the set up. A facilitator controlled the role play with participants from different disciplines such as nurses, doctors, cleaning personnel and others. For different types of patients, the actors should play through scenarios from planning the arrival of the patient, receiving the patient and following the route of patient and personnel through different rooms during the treatment. Since only a minor part of relevant equipment was represented on the floor plans or as artefacts, many questions and uncertainties arose during the role play regarding which equipment would be available in specific situations.

IDENTIFICATION OF FUNCTIONAL REQUIREMENTS

The researchers' observations of existing processes in the case studies and interviews with professional process facilitators as well as end users from different staff categories led to the identification of a number of relevant functional requirements for a Virtual Reality system which would have the potential to partly replace or complement some of the work with physical mock-ups. The identified requirements are summarized below.

The working processes often include closely related activities taking place in a number of rooms with different functionality. Thus it should be possible to study aspects of affinity between rooms with different function. The end users should have the possibility to identify and comment on rooms' functional requirements while they are in the virtual envi-

ronment.

Ideas for alternative room layout often emerged during the test sessions in the physical mock-ups. In the virtual environment, it should be possible to easily model room layout including positions of walls and interior to quickly view and discuss consequences of a design idea. In addition to this, it would be important to be able to save comments, descriptions of design ideas and decisions made in the virtual environment to communicate this knowledge back to designers and capture design rationale.

From a technical point of view, it would be an advantage to have a good connection to existing tools used in the specification of requirements to rooms and their equipment including CAD/BIM tools that would be used by the designers. Similarly, it would be relevant to have connectivity to existing document management systems used by the design team on the specific project.

In the case studies, it was found that missing equipment or too simple or too abstract representations of equipment or building parts as e.g. windows often led to confusion and misunderstandings during the test sessions. Here, the virtual environment has the potential to add value by better visual representations of equipment and building parts. Thus, the objects in the virtual environment should appear visually realistic in size and shape. Figure 4 shows an example of a toileting chair in sufficient level of detail to the right and too simple to the left. The graphic quality will especially help end users with little or no experience in reading technical drawings who asked for a realistic impression of the spatial aspects of the room interior.



Figure 3
Users in role play
around tables with
floor plans and
scale models of
personnel and
equipment.

In all the case studies, the real time dialogue between users proved to be valuable for the decision processes. To have a similar functionality in the virtual environment, several users should be able to interact with the model in real time, e.g. to enable 'role playing' in the investigation of future working routines in the proposed building design.

PROTOTYPE DEVELOPMENT

Based on a review of available technologies, e.g. (Mihelj et al, 2014), (Johansson, 2012) and the detailed studies of existing workflows and needs in the design process, a first prototype of a system to support user involvement in the interior design was developed including a few of the identified needs identified above. The prototype was based on the Unity Game Engine, an Oculus Rift Head Mounted Display (HMD) and a touch screen, where end users could intuitively move equipment and room boundaries in floor plans based on the architect's design proposal. Figure 5 shows the prototype ready for use in the lab and figure 6 shows a screenshot of the initial user interface.

During the development process, factors influencing the user experience in the virtual environment were examined through a literature review, where depth perception, complexity of the virtual environment, presentation quality, motion tracking and cyber sickness were some of the topics discussed (LaViola 2000; Bowman et al. 2007). Two detailed tests were carried out, where models from the building designers BIM-environment were transferred to the virtual environment and tested with users to identify potential obstacles.

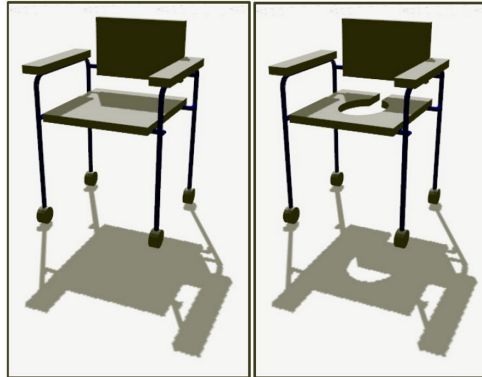


Figure 4
Toileting chair
shown in different
level of detail.



Figure 5
First prototype
ready for test in lab.

Figure 6
Screenshot of touch
screen user
interface.



Figure 7
Users preparing test
scenario.

The clarification of needs and review of technical and human factors that affect the use of Virtual Reality formed the basis for a system design, where existing workflows were redesigned into a vision for the future work practice. A prototype allowing end users and design facilitators to design and configure the workspace, and thereafter test it in Virtual Reality was then developed.

EVALUATION AND CONCLUSIONS

In order to validate the usefulness of the vision, a number of evaluations of the developed prototype were set up. Through "quick and dirty" feedback sessions with users and experts of user involvement, along with a series of field studies, the user experiences of the interface and Virtual Reality were examined. Figure 7 shows users preparing a test scenario and figure 8 shows a user navigating in the test environment.

The evaluations showed that even high-end computer systems can easily become overloaded resulting in reduced performance of the VR system. When a user involvement system should be used for the construction of large hospital buildings, it is therefore essential to prevent such failures in performance and to design the system so as to maximize the usefulness of the available hardware. The evaluations of the developed prototype with end users confirmed that the virtual mock-ups have a potential in user involvement. Users agreed that the system's basic features in several areas supported their needs, especially on issues regarding spatial understanding. However, the evaluation exercises also demon-

strated that usability of the equipment plays a significant role, since some of the users found it challenging to move objects on the touch screen and a number of users experienced varying degrees of cyber sickness. Overall, the evaluations confirmed that the combination of head mounted displays and a touch screen for manipulating the design can contribute to the user involvement process in interior design of hospital buildings.

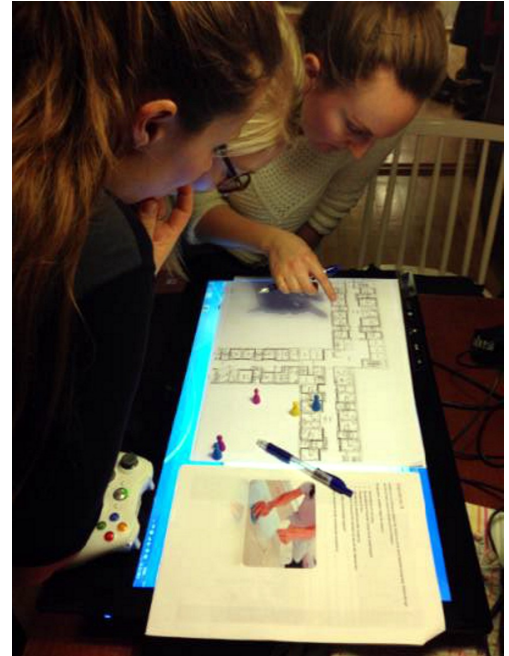
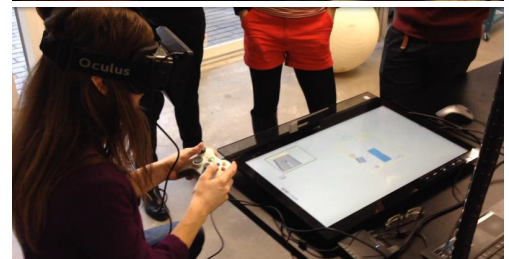


Figure 8
User navigating in
the virtual
environment while
colleagues are
following her view
on the touch
screen.



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