INCREASED INTERACTION WITH MULTI-USER VIRTUAL REALITY IN CONSTRUCTION PROJECTS

Janne Porkka, Nusrat Jung
Technical Research Centre of Finland, Espoo, Finland

Sunil Suwal, Päivi Jäväjä
Metropolia University of Applied Sciences, Helsinki, Finland

Anssi Savisalo
FCG Finnish Consulting Group Ltd., Helsinki, Finland

Jani Päivänen
WSP Finland Ltd., Helsinki, Finland

Jarkko Sireeni
Vianova Systems Finland Ltd., Espoo, Finland

ABSTRACT: During last decades the rapid development of ICT has strongly reformed architecture, engineering and the construction industry. Model-based applications, such as building information modelling (BIM) and urban planning tools, are being used by architects and engineers for increasing their productivity. These tools are a promising platform for planning, but more user-friendly interaction is needed for communicating plans to other stakeholders and end-users.

This paper introduces an approach where virtual reality applications, together with participatory design and collaborative design approaches, are used in order to improve interaction and communication between various stakeholders in urban planning projects. The approach deploys experimental multi-user virtual reality environment in design review meetings carried out in two urban planning projects in Finland. The environment consists of three adjacent large wall displays positioned at 45 degrees angle between each other. Navigation in the model is performed by multi-touch gestures on a large tabletop interface. The first case study, an area development in Inkilänportti retail area harnessed virtual reality for collaborative design review meeting between the client and multiple design fields. In the second case study, virtual reality was utilised for a participatory concept development of Finnoo-Kaitaa city district.

Based on the feedback from participants, visual communication has its benefits when compared to traditional meetings. The empirical findings collected through self-completion questionnaires from the participants of meetings indicate a positive attitude towards the new technology uptake. Virtual reality applications are a very promising channel for client and user participation, and as well, help to bridge the social interaction gap between industry professionals and non-experts, whose participation is also crucial to successful urban planning. Urban plans are usually large and complicated. Therefore, effective visualisation is significant for successfully understanding the spaces, dimensions and associated atmosphere indicated by design solutions.

KEYWORDS: Construction industry, Model-based design, Virtual Reality, Design review, Interaction.

1. INTRODUCTION

During last decades the rapid development of ICT has strongly reformed architecture, engineering and the construction industry. Ground rules for planning processes are generally described in national land use and building acts. Major development projects within the industry usually take long time to proceed, even up to 25 years or more (Porkka et al. 2012). Moreover, the industry is constantly struggling to unite fragmented building and infrastructure data sources and databases. In relation to ICT in construction industry, model-based applications, such as building information modelling (BIM) and urban planning tools, are being used by architects, engineers, and planners for increasing their productivity. Eastman et al. (2008) stated that BIM in particular is an emerging technology for building modelling, collaborative design, and integrated project deliveries.
These model-based tools are a promising platform for planning, but more user-friendly interaction is needed for communicating plans to other stakeholders and end-users. A participatory approach requires interaction with users, making it even more complicated to convey the design proposal in a simplified representation. The users may lack skills, knowledge and understanding to evaluate the substance. A traditional design communication at an early project phase is often built on a paper-based graphical representation, consuming time and limiting the opportunities for team work. Virtual Reality (VR), in particular, has been said to offer promise for design visualisation to convey messages without communication difficulties (Reich et al., 1996). Visualisation is the easiest common language for all stakeholders, where professionals and non-specialists are able to relate and understand the content of design proposals.

Virtual Reality applications have been harnessed to production by many industries. New product development and communication in automotive, aviation, maritime and military industries have benefitted from them (Brooks, 1999; Gould, 2009) and interaction in projects is more effective (Ganah et al., 2005). The construction industry, however, has been slow in adopting new virtual reality applications to processes. The implementers have reported great benefits (Dawood, 2009), for example to help in bridging the communication gap between planning and design professionals and non-experts. Since large development projects usually involve a great number of stakeholders, the success in communication is a necessity for stakeholder contribution. Processes are urgently in the need of easily understandable material for decision makers, who because of distinctive backgrounds might be inexperienced over the domain specific details.

To enhance interaction, design reviews are a promising playground for virtual reality implementations. The development process in project includes various design field collaboration through multiple phases. A planning coordination approach in relation to a land use, infrastructures, buildings, energy, and environment needs to be thoroughly considered (Porkka et al. 2012). The goal of design review is to spot, as soon as possible in the production chain, product and process weaknesses, errors and potential problems (Uva et al., 2010), to help in finding opportunities for creating new alternatives. Further, a design review improves stakeholder communication, saves costs and prevents possible delays (Carlin, 2010). Since the renewal of Land Use and Building Act back in 1999, participation has widely been encouraged and actively discussed in Finland (Olsson et. al., 2012). Participatory design approach is an emerging process where users’ feedback is considered and their opinions have an influence on the planning (Jäväjä et al., 2012). Virtual reality applications have recently started to be included in participatory design methodology (Mobach, 2008) and they increasingly provide opportunities also for collaborative design. Thorough implementing both approaches, the collaborative and participatory methodologies, the projects are more likely to succeed.

This paper introduces an approach where virtual reality applications, together with participatory design and collaborative design approaches, are used in order to improve interaction and communication between various stakeholders in urban planning projects. The approach deploys experimental multi-user virtual reality environment in design review meetings carried out in two construction projects in Finland with positive results on increased interaction amongst the stakeholders.

2. VIRTUAL REALITY ENVIRONMENT UTILIZED IN CASE STUDIES

The use of virtual models is becoming more stimulating among the municipalities and various developers in Finland. Within the last few years, a term ‘city model’ has been discussed in the planning and built environment curriculum. The term was introduced for a process to maintain an up-to-date building and infrastructure model revision for the city area. Later, the model is being utilised efficiently for land use planning and construction projects (Vianova Systems Finland, 2012). The city model is an immediate tool between multiple stakeholders, especially during planning and design phases. Besides, the model highlights the communication between the city officials, design consultants and contractors, enabling the municipalities to provide better solutions and services. In future, new building permit procedures, where one can extract specific site data as per one’s need, may be submitted to the authorities and managed digitally.

One of the cities employing the ‘city model’ in practice is Tampere, which is the third largest city in Finland located 200 km north from the capital (Tampere, 2012). The city is located between two lakes, a river and a railroad dividing the centre. An example of a ‘city model’ is presented in Figure 1.
This paper draws from the case study findings. A virtual reality environment called ‘Innovation kitchen’ at VTT Espoo has been utilized to increase interaction between the stakeholders. The multi-user virtual environment, shown in Figure 2, consists of three adjacent large back-illuminated projection walls adjusted at an angle of 45 degrees. There are two projectors and a dedicated PC operating each of the 3x2 metre display walls. The control of graphical outputs has also a connection matrix. The matrix enables connecting the laptops of meeting participant to the displays. To avoid potential problems in the meeting contribution, stereoscopic visualisation produced with polarisation filters and glasses was not used in case studies. Large projection-based immersive environments are potentially ideal to experience a shared virtual environment, collaborate and exchange ideas (Simon and Scholz, 2005).

The navigation in the environment is performed with multi-touch gestures on a large custom-built tabletop user interface (Harviainen et al., 2011). The solution consists of an ordinary LCD display, 4 cameras, illumination bands, and an in-house VTT developed software to compute the finger location from shadows. The multi-touch gestures enable users to move in the model environment with the help of an intuitive map interface. Location and orientation messages are sent wirelessly as UDP (User Datagram Protocol) messages from the tabletop to the backend PCs. The terrain model is visualized in the development version of Vianova’s Novapoint Virtual Map viewer.

Vianova’s Novapoint Virtual Map is an add-on tool on top of AutoCAD. It creates a visually rich real-time virtual model automatically from the input data. The application has two modules; a model builder running in
AutoCAD for generating models, and a standalone viewer for visualising and distributing the models freely. The model builder produces a complex 3D model from an input data, with parametric rules containing modelling layers, materials, geometries and object relations. Materials and textures are attached to objects automatically. Currently, the supported data exchange formats in Virtual Map application are DWG, DWG+XREF, LandXML and Civil3D DWG.

3. INTERACTION IN TWO CASE STUDIES

This article builds on empirical findings from two Finnish cases. The first, an area development in Inkilänportti retail area, which harnessed virtual reality for collaborative design review meeting between the client and multiple design fields. In the second case study, virtual reality was utilised for an interaction in the concept development of Finnoo-Kaitaa city district.

3.1 Inkilänportti retail area development in Kirkkonummi

The future Inkilänportti retail area is located in Kirkkonummi municipality about 25 kilometres west from the centre of Helsinki city (Kirkkonummi, 2012). The planning area covers 50 hectares of land, which at present is predominantly forest with sparse settlement. The development is located at a strategic point, where the main road artery (Highway 51) westwards from Helsinki city meet the end point of the outer Ring Road III. This gives a lucrative position to commercial development. Total floor area of the development will be approximately 100 000 square metre. The development will be connected to the surrounding future housing areas, as well as a nearby railway station, with a network of bicycle and pedestrian routes. A direct bus connection towards Helsinki city and Kirkkonummi centre connects the development area to public transport.

FCG Finnish Consulting Group Ltd. has been commissioned by landowners to prepare a detailed city plan (asemakaava) and preliminary plans for infrastructure and public areas to the area (Jäväjä et al. 2012). Planning is based on the Greater Helsinki regional plan (maakuntakaava) from Uusimaa regional council in 2006 and general plan (yleiskaava) from Kirkkonummi municipality published in the year 2006. The general plan is being revised by the municipality in a separate simultaneous process, which will end in a detailed general plan (osayleiskaava) in the surrounding Inkilä area. The detailed city plan (asemakaava) will be subjected to political decision making by the end of 2012. At an early stage of planning, it became apparent that the complexity of the planning object and the on-going simultaneous processes pose an exceptional challenge for project management. An innovative use of BIM in project management, collaboration and communication within the planning team and towards the other stakeholders (planners, land owners, citizens, municipality and regional authorities) is an effective tool for the project (Jäväjä et al., 2012). Screenshots from the Inkilänportti retail area project are shown in Figure 3. The general Landscape Information Model (LIM) overview is presented on the right, and left section shows details from an adjacent existing housing area.

Fig. 3: Screenshots from Inkilänportti project (photos on the left by Janne Porkka, model image on the right courtesy of Skanska CDF Ltd., SRV Group Ltd., Vianova Systems Finland Ltd. and FCG Finnish Consulting Group Ltd.).
3.2 Finnoo-Kaitaa district concept development in Espoo

Espoo, with the population of 250,000, is the second largest city in Finland. The special feature of city is an urban structure that relies on five different centres combining urban, suburban and rural living (Espoo, 2012). The city includes also wide-reaching natural areas, international companies and Aalto university campus. Finnoo-Kaitaa district is situated on the coastline, fifteen kilometres from the Helsinki city centre. The forty-seven hectare area is at present largely unconstructed, and projected at nearly 20 000 inhabitants and several thousand jobs in future (WSP Finland, 2012).

The collaborative land use planning for new area vision led by multidisciplinary consulting firm WSP Finland Ltd. started in the year 2009. The starting point for the development process was from ‘an open ideas evening’, and since then, workshops on different themes were arranged to complete a shared vision. Themes discussed at workshops were city structure, energy, nature and recreation, architecture and housing, and finally livelihood and services. For the final evaluation, a synthesis was drawn from freely presented and developed ideas. New Finnoo underground metro station is the focal point of several on-going development plans. Many participatory methods activating residents, non-governmental organisations, various professionals, and city representatives are being used within the development.

The target is to create an urban maritime district, which some participants coined as the ‘Venice of Espoo’. However, the area aims at being recognized regionally for a wide range of ecological built environment including a water research centre, carbon neutral housing, business and leisure. Architecture in blocks near the metro station is of a high quality and social places are easily accessible for residents. The area provides a variety of pedestrian routes and public spaces spiced with exciting artworks, light installations and greeneries. The preliminary plan of metro station with surroundings is illustrated in the Figure 3. The plan was drafted by Helsinki-Zürich architects Ltd, and is at the time being further developed by WSP.

![Fig. 3: Preliminary plan of metro station with surroundings.](image)

4. RESULTS FROM UTILIZING VIRTUAL REALITY IN PRACTICE

The project management of both case studies perceived the coordination benefits by use of model-based tools since the early planning. These applications appeared to support various stakeholder viewpoint considerations in relation to design content. The model-based tools tend to give an important, easily communicable data for process analyses. The Novapoint Virtual Map viewer application was used in both case studies for design review meetings. The research setting used the participatory methods in order to assist conversations between the stakeholders, including clients, multiple design fields, architects, construction companies and other interested participants. The sample size for a self-completion questionnaire was entirely 24 professionals, 14 men and 10 women, with ages ranging from 23 to 60 years. The meetings clarified that the industry needs common
agreements and data exchange standardisation for presenting correspondingly land use, infrastructures and building data. We used the tailor-made viewer, to present a myriad of design content.

A traditional design review meeting was the research setting in the Inkilänportti retail area development project. The virtual model produced by Vianova Systems Finland Ltd. combined various design field 3D plans, such as ground model, source data for landscape, buildings from two architects, motorway, roads, streets, intersections, storm water and pedestrian routes. The integration model was an addition to a traditional work meeting, where each member of the design team usually introduces individual models. The virtual model approach helped to identify integration difficulties, such as a large elevation difference between two lots, need to redesign an intersection and to reconsider few pedestrian routes. The navigation was performed by a facilitator, mostly from flyover perspective, and when challenges where positioned pedestrian perspective was also used. The input and comments where documented to a meeting memo like in a traditional meeting, but also comments were attached directly to the Virtual Reality model. Later, the model coordinator delivered the commented Virtual Reality model to all participants.

Within the other Finnoo-Kaitaa case study, virtual reality application was used to enable better communication between stakeholders at early district concept development workshop, where an increased interaction was highly appreciated. The virtual model was developed by WSP and the workshop focused on the livelihood and services within the area. The use situation at second case study utilised virtual model to motivate workshop participants to have dialogue and discuss about the plan characteristics. The workshop organisers collected feedback and reviewed comments. Relevant issues where later changed at the development plan. The city officials noticed during the meeting that flat land causes sight problems to the area. The intention is to develop a new maritime district, but buildings and trees planted in pedestrian walkways block the sight to the shoreline. The elevation problem needs further improvements, like location and height considerations. Photos in Figure 5 elucidate the research setting in both case studies.

Fig. 5: Photos from the case study meetings; a work meeting in Inkilänportti project on left and interaction at Finnoo-Kaitaa concept development workshop on right (photos by Janne Porkka).

The stakeholder feedback from the meetings was collected with similar self-completion questionnaires. The inquiry targeted on to evaluate the acceptance of technology and to capture what kinds of influences the use of virtual model has on understanding the design content. The questionnaire included nine fixed questions, to be answered on a scale of 1 to 7, spanning from totally disagree to totally agree. Empirical results are summarised in Table 1.
Based on the feedback, 88 percent of the participants reported clear benefits from the model use, and likewise, are interested in utilising a similar technology in future. Additionally, the multi-projection wall solution supports comprehensibly the increased design content understanding (67% agreed) and is considered as a suitable presentation format for the meeting (75% agreed). The realism in virtual models was reflected neutral by 58 percent of the observers. We also had a facilitator assisting in the movements within the environment. All respondents were neutral or liked the model navigation, although nearly all were first-timers in experiencing the virtual environment, and none felt the environment physically unpleasant either.

Table 1: Summary of empirical results as seven-scale percentage values (%) in Inkilänportti and Finnoo-Kaitaa case studies (sample size 24 respondents).

<table>
<thead>
<tr>
<th></th>
<th>Tot. disagree</th>
<th>Neutral</th>
<th>Tot. agree</th>
</tr>
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<tbody>
<tr>
<td>Q1. Meeting was successful</td>
<td>0</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Q2. Meeting benefitted from virtual model</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Q3. Helps to understand design content</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Q4. Suitable presentation format for meeting</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Q5. Virtual model felt realistic</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Q6. Movement in model was normal</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Q7. Physically unpleasant experience</td>
<td>58</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Q8. Interest to use technology in future</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Q9. Interest to test model via Internet in personal computer</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
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The two case studies have differences in a project size, the restrictions by surrounding area plans and structures, which also reflects partially on interaction. The scale of design options was more compact in Inkilänportti case study. Therefore, the discussions were also focused and issues like the elevations and levels of existing ground with respect to the plan were considered. Whereas, in Finnoo-Kaitaa the concept development of unconstructed area covered many viewpoints, abstract thinking being at the preliminary level for the district development.

The quality of virtual model is an interesting, and partially biased topic. For expert communication, where participants are likely to understand the substance precisely, a realistic visualisation seems to be an interaction enabler. We tried to minimise the amount of manual work at the virtual model creation and visual quality was not a priority. Instead, the priority was to have a virtual model helping the planning coordination. A well-managed navigation deemed an essential part of a meeting, since the designs usually are reviewed in the patterns of solutions. Virtual environment enables easier interaction and helped to understand complex projects through visual aids. Urban planning projects are complex in nature, the size of project and the participants have a straight impact on how one can quickly and easily perceive the project. As identified within both cases, going through the key stakeholder perspectives at the early stage help to avoid flawed decisions. These flawed decisions may result later in compromises and potentially unsustainable development (Isaacs et al., 2011).

5. DISCUSSION AND CONCLUSION

For efficient communication, land use development and construction projects are a challenging domain. The empirical findings collected through questionnaires from two case studies, a retail area development and the concept development of city district, indicate a positive attitude towards the virtual reality technology uptake. The two case studies are different in the project size and restrictions, reflecting partially on interaction. In the retail area development project, the scale of design options was more compact with focused discussions. Whereas, in the other case concept development called for relatively abstract viewpoint considerations.
Multi-user virtual reality applications were seen as a very promising channel for collaboration and participation. A vast number of respondents were able to realise clear benefits from virtual reality. An immersive wall solution increases the understanding of design content and fits well into the meeting presentations. On the other hand, the novice virtual reality utilizers may be overwhelmed about the immersing technology, which surrounds the observers. Still, we argue that virtual reality applications are a very promising channel for client and user participation, and as well, help to bridge the social interaction gap between industry professionals and non-experts, whose participation is also crucial to successful urban planning.

An effective visualisation is significant for successfully understanding the spaces, dimensions and associated atmosphere indicated by design solutions. This is similar to collective intelligence, which tries to understand the relations of various objectives, agree on common targets and detect promising opportunities (Päivänen, 2005). The urban development is currently aiming at understanding the components of functional areas and how social problems are avoided with the help of detecting the neighbourhood signals.

The rapid pace of technology advancement has influences on virtual technologies. Recently, the applications have been overlapping video game industry (Smith & Trenholme 2009; Kaplan & Haenlein, 2010; Yan, Culp & Graf 2011). Serious gaming applications complement the existing applications to a better visual performance and an enhanced user-friendliness. The gaming is also a path opening towards a multi-platform support. We asked in the questionnaire opinions on the web models, and interestingly, nearly all respondents were in favour of using Internet as a distribution channel. What if the models in future are reviewed on a web-based multi-user environment?

6. ACKNOWLEDGEMENTS

This research has been supported by the Finnish Funding Agency for Technology and Innovation (TEKES) under the project PRE/BIMCity (dnr 1954/31/2010). Authors want to express their gratitude to stakeholders in two case studies, especially project development director Kari Hovi in Skanska CDF Ltd. and Finnno-Kaitaa project manager Torsti Hokkanen in the city of Espoo. Main and the second author are doctoral candidates in Finnish universities. Janne Porkka in the Faculty of Built Environment at Tampere University of Technology and Nusrat Jung in the Department of Energy Technology at Aalto University. Special thanks for our colleague Kari Rainio at VTT for assisting in virtual space arrangements and helping in technical description.

7. REFERENCES


