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# Inside - Outside Model Viewing

## *A Low-cost Hybrid Approach to Visualization and Demonstration of 3D Models*

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**Keywords:** Virtual Reality, Augmented Reality, Real-time Rendering, Head Mounted Displays.

**Abstract:** Visualization of large scale 3D models has become an important part of the development cycle in many fields like building design, machine design, construction and many more. Whether for design communication or demonstration, it is necessary for the viewers to fully understand the different components of the model, their proportions compared to each other and the overall design. A variety of augmented reality (AR) applications have been created for overall visualization of large scale models. For tours inside 3D renderings of models many immersive virtual reality (VR) applications exist. Both types of applications have their limitation, omitting either important details in the AR case or the full picture in the case of VR. This paper presents a low-cost way to demonstrate models using a hybrid virtual environment system (HVE), combining virtual reality and augmented reality visualization. The solution is built using a fully occlusive head mounted display (HMD), together with off-the-shelf web cameras and a game controller for interaction. A proof of concept is created using a commercial game engine, which is used in a subsequent case study. Based on this study, we demonstrate the validity of our proposed system.

## 1 INTRODUCTION

Virtual Reality (VR) technology has started to gather a lot of follower in recent years, thanks to both the push of large companies and the emerging of the new low-cost, easy to use, lightweight and high resolution Head-Mounted Displays (HMD). And with the development of faster mobile and camera solutions and more robust tracking algorithms AR has also been on the rise. These solutions make it possible for developers to build real-time mixed reality (MR) applications. A problem that arises with the development of virtual reality systems is the one of visualization and proper interaction with the objects in the environment. To achieve a proper experience of immersion and interaction with the environment different methods are explored. The most recent state of the art research methods concerning tablet-based interaction (Krum et al., 2014), as well as gesture-based ones (Shen et al., 2014).

Another possibility for helping the user to properly interact with the virtual environment is by providing a better and more diverse outlook on it. This can be achieved by implementing a virtual reality system, that uses a combination of multiple points of view and

interaction possibilities. Such systems are demonstrated in (Wang and Lindeman, 2014) and (Wang and Lindeman, 2015), where multiple points of view and methods of interaction ensure a smooth workflow and interactions for users.

This paper introduces a novel approach based on this type of hybrid virtual environment system, which uses a mixed reality visualization. We focus on a low-cost hardware system using an Oculus Rift DK2, as a HMD, together with two web cameras for passthrough. For interaction an Xbox360 controller is chosen for its relative simplicity and versatility. Two visual points are implemented - a first person view and a bird's eye view. The bird's eye view of the models is rendered as an augmented reality visualization on a marker connected to the controller. The first person view employs a virtual reality approach to go up close to different parts of the 3D model and get a better understanding of their proportions. In addition the starting position of the first person view can be changed by users, providing a more customizable experience. A user study was conducted to validate the approach and demonstrate its positive effects on an user's workflow. Furthermore, the mixed reality approach reduced cyber sickness.

## 2 RELATED WORK

### 2.1 Immersive Virtual Reality Applications

Immersive virtual reality applications have become a commonplace in number of different fields, that require visualization of designs in work or finished products without the need of a physical product. Such fields are architecture, engineering, and construction. Efforts have been made to implement this kind of interactive visualizations into the pipeline of CAD/CAM production, such as the work of (Stark et al., 2010) and integrating it as part of a product lifecycle management, as in the work of (Mahdjoub et al., 2010). Additionally, such immersive virtual reality applications are becoming more and more easy and natural to work with, removing inherent limitations such as user fatigue, uncomfortable controls and disorientation. The research of (Mine et al., 2014) works around these limitations to achieve an application that can be used for longer periods of time. It is also shown that immersive virtual reality application can be a vital part of the demonstration process, giving more information to users, which could not be shown as directly in any other way. The research of (Marks et al., 2014) demonstrates the validity of this for the ship construction industry, while the work of (Bednarz et al., 2015) shows the positive effects of immersive virtual reality applications on the mining industry.

### 2.2 Augmented Reality Applications

Augmented and mixed reality applications have become regular substitutes for bulkier and harder to move and assemble models and miniatures. These applications are commonly used for building visualizations, machine and parts demonstrations. Other strengths include the expanded degrees of interaction and user involvement, as well as the comfort of using a wide array of platforms to work with. Fast access to vital information throughout the design and construction phases of buildings is a necessity and the work of (Zollmann et al., 2014) shows that augmented reality visualization can give this kind of information. A combination between 2D schematics and 3D augmented reality visualization gives all necessary data, without interrupting the workflow, as shown by (Côté et al., 2014). The acceleration of decision making in construction using AR is further demonstrated by (Wang et al., 2014). (Figueiredo et al., 2014) show that visualizing 3D models for demonstration

and training purposes using an augmented reality approach also gives a better outlook on them.

## 3 METHODOLOGY

### 3.1 Visualization Rig

The visualization rig consists of a number of major components, that work together to achieve both the first person and the bird's eye views of the models. The components are as follows - a consumer grade VR headset, two identical off the shelf web cameras fixed in stereoscopic view on a custom mount, two smart phone fish-eye lenses for extending the field of view of the cameras, an augmented reality target tracking system and a rendering engine.

The VR headset in use is a Oculus Rift DK2, which offers marker based tracking of linear head motion using infrared LEDs on the headset and a single infrared sensitive camera. The headset can also track rotational head movements thanks to the built-in accelerometers. Because the proposed system does not require free physical movement, these out of the box capabilities are enough for a proper visualization. As the headset provides a fully-occluded virtual reality visualization and the mixed reality approach of the solution requires passthrough capabilities, a custom solution needs to be build. Two identical Canyon CNE-CWC3 web cameras, together with iPhone fish-eye lenses are chosen for the project, as they provide an inexpensive solution with 1080p resolution, 45 fps and wide field of view and thus minimize the symptoms of cyber sickness described by (LaViola Jr, 2000) and (Sharples et al., 2008). Both cameras are mounted onto Oculus Rift so they can form a comfortable stereoscopic view with eye distance of 6.35cm. As the aim of the project is to create a low-cost, easily replicated, mixed reality viewing solution for our approach, we voted against using professional machine-vision cameras.

### 3.2 Augmented Reality Solution

For visualization of the 3D models onto the passthrough video feed, a augmented reality target positioning solution needs to be chosen. Going again with our goal to make reimplement and subsequent experimentation easier, we chose a free tracking solution. A second requirement to our solution is that it would be able to work properly with both desktop and mobile systems alike. The third requirement is that the solution needs to be compatible with the Unity game engine. Taking in consideration these

requirements we chose the free, easily convertible implementation of ARToolKit, called NyARToolKit. More information on the library can be seen in (NyA, 2015).

As virtual interactions are done through the use of a Xbox360 controller and the user would be engaged in holding the controller, a solution is offered for physically interacting with the marker for tracking, without letting go of the controller. The target marker is mounted on top of the controller, giving the user the comfort to rotate and move the marker, while interacting with the 3D model rendered on top of it, through button and stick manipulation. The final prototype rig and the controller-marker rig can be seen in Figure 1.



Figure 1: Left - the hardware rig consisting of an Oculus Rift DK2, dual web cameras and fish-eye lenses. Right - the marker-controller rig with custom made marker. By combining the two, both physical and virtual interaction can be achieved at the same time, while in the bird's eye augmented reality view.

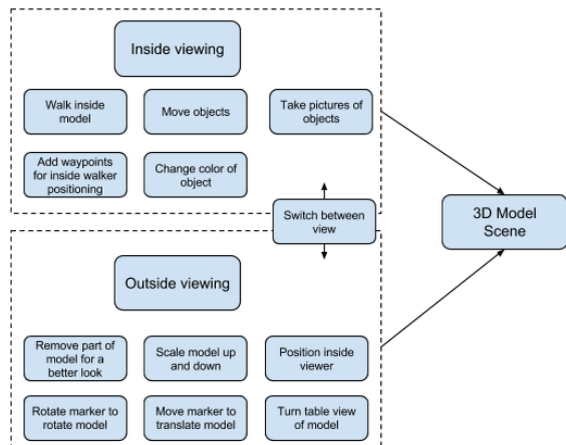


Figure 2: Implemented interaction for the prototype. Divided in inside and outside interactions, depending on which view they suit best. The selected interactions are the ones most widely used in the state of the art research.

### 3.3 Proof of Concept Application

As part of demonstrating the capabilities of the suggested approach, we build a proof of concept application using the Unity 4.6 engine. A number of interaction possibilities are implemented into the applica-

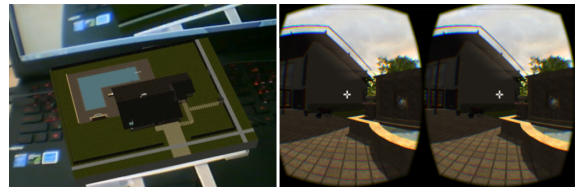


Figure 3: Overview of the two views implemented in the prototype - outside bird's eye augmented reality view and inside first person virtual reality view.

tion. These interactions are chosen in such a way that they may be used to test user's experience, while manipulating parts of the application. Additionally these interactions are the most widely used in the state of the art research of immersive virtual and augmented reality interactive systems like the ones described by (Seftoe et al., 2014), (Wang and Lindeman, 2014) and (Wang and Lindeman, 2015). These interactions are divided into inside and outside interactions, depending on which view they suit - the first person one or the bird's eye one. The selected interactions and the view to which they are allocated can be seen in Figure 2.

A free model of a villa is selected, as to offer diverse interior and exterior objects and wider spaces for easier testing. The model is rendered differently for the outside and the inside views. For the outside view the 3D objects are rendered with only basic lighting and shadows and without any advanced screen effects or animations. This is done to make the model as lightweight as possible and to help the user focus on the model itself without any additional distractions. The inside view model is much more detailed, to compliment the immersive nature of the view. A skybox, realistic water, particle effects, trees and surrounding terrain are added. Visualization of both view can be seen in Figure 3.

The switch between the two views is achieved by a combination of two effects - a smooth transition of the camera from one position to the other, combined with a fade to black effect, to prevent the disorientation of the user.

Another idea that we implement and which is possible by the combination of virtual and augmented reality visualization is a passthrough "window", to the real world, when a user is in the virtual reality first person view. This is implemented to lower the possibility of disorientation or cyber sickness. The positive effect of giving the user the possibility to view his or her body and the real world is demonstrated by (Buchmann et al., 2005) and (Bruder et al., 2009). Thus, a user can orientated himself/herself better, as well as get a fast look on the outside view without breaking the immersion of the inside viewing of the

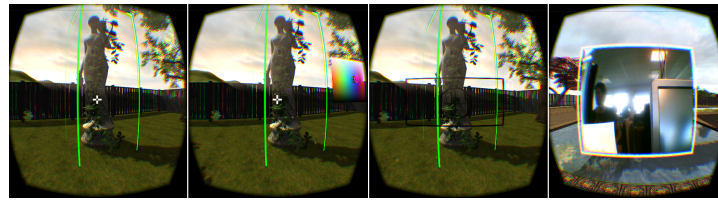


Figure 4: Examples of the interactions in the inside virtual reality first person view. From left to right - interact with selected object, change color of selected object and take a photo of what the user is seeing plus creation of waypoint for later return to that point in the 3D model. Final image demonstrates the passthrough "window" to the real world.

model. Some examples of the possible interactions are given in Figure 4.

## 4 EVALUATION

### 4.1 Usability Study Overview

The prototype inside-outside model viewer is tested in a preliminary user study with a number of participants with various work and study backgrounds. The participants are chosen from both genders and from different age groups. In total 12 participants are featured in the study, from which 4 female and 8 male. The users are roughly divided into categories depending on their background and computer knowledge.

The first group of 7 participants has high degree of computer knowledge and have used or observed the use of a HMD in relation to their academic background, as well as those who have mixed skillsets in design and have worked with modelling and CAD applications. The second group of 5 contains participants from a background in humanitarian sciences - tourism, economics, marketing and management and have a lower degree of computer knowledge.

The study determines the feasibility of our proposed system, by giving users the possibility to interact both with the bird's eye and first person views. Additionally, to avoid biased results towards users who are well versed in working with modelling programs or have experience with virtual reality, the testing is also conducted on users which have little or no such experience. The study consists of an initial calibration and a number of testing scenarios. A free-flowing, think-aloud method with a relaxed approach is used for conducting the study, similar to the one used by (Zhao and McDonald, 2010). This helps the researcher to get an intimate look into the experience and thought process of the participants. A seven point system is chosen over the normal five point one, as it is shown to receive less neutral answers, with lower measurement error and higher precision by the research conducted by (Munshi, 2014).

### 4.2 Results

When we asked about the degree to which the combination of the two views would help for the overall understanding of the model, participants were polarised in their responses dependent on their skill set. Seventy five percent of the users with non technical skill sets, as well as ten percent of users with technical skills felt a detached between the outside and inside views. Answers like - *"...for me the two views were too different so I could not even match them in my head. For me they gave me a lot of information but I could not connect it."* and *"No, because you had to focus a lot on that one (outside view) first. You could see everything on the model, but the moment you go down you lose the sense where you are...But maybe it was because I did not zoom out that much."*, demonstrate the problems, which the users were facing. The sheer amount of information that the users get from the setup can be overwhelming and requires a certain time to get used to, by inexperienced users. Figure 5 demonstrates the difference between the conclusions of users from the demographics. Both the inside and the outside views were positively accepted, with all users appreciating both the model in hand approach of the augmented reality, as well as the hands on experience of the virtual environment

On the other hand most of the participants with technical and design background were positive that the hybrid setup helped them. The selection where a user can place the inside walker was considered also a feature which helped orient the users. This is indicated by comments like - *"The two views help. I can go and look at the whole thing and then select where I want to be. Less walking around and it's more interesting"*. Furthermore, all participants also easily got into the workflow of using the two views, switching between them after interacting with parts of the models and searching for new ones to interact with or looking how they look like in the bird's eye view.

In addition even though most participants felt that the transition from outside to inside view is smooth and gave them a deeper feeling of being there once in the inside view, the same was not considered for

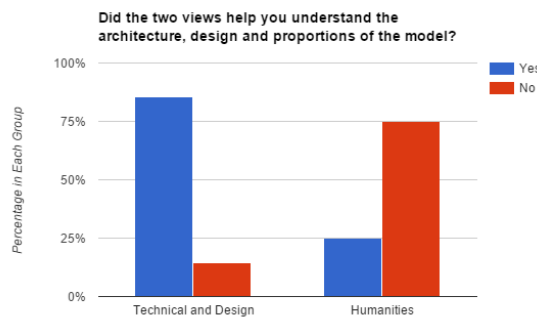


Figure 5: How the users found this paper's approach helpful for viewing and understanding the overall proportions and size of the 3D model and its parts.

the reverse transition. Users generally felt disoriented and dizzy once coming back to the outside view. This presents a problem, as constant switches between the two views are required for normal work with the prototype. A suggestion for alleviating this problem is making the switch to outside view much slower as well as giving information to the user, how he or she is oriented in the real world before the transition is done.

Another aspect that is taken into account in the user study is the degree to which participants developed symptoms of cyber sickness, as our proposed setup was also directed at alleviating nausea, dizziness and disorientation. This is why we asked users if they experienced any symptoms. The answers show that more than half of the participants experienced varying levels of discomfort and disorientation. It is also seen that most of the symptoms were experienced in the inside view, where the users are subjected to a full virtual reality. The results are visualized in Figure 6. Most users indicated that the switch between the two views was very helpful with removing most of the effects from the inside view, as well as helping them orient themselves in the real world after longer use. The outside view "window" was also helpful with that, as well as with making communication with people in the "real world" easier.

## 5 CONCLUSION AND FUTURE WORK

The paper outlines our suggested flexible and low-cost approach for combining virtual and augmented reality visualization for a more comprehensive 3D model demonstration. The approach centres around a two-view system - an inside first person virtual reality view and an outside bird's eye augmented reality view. A unified control scheme makes interactions in

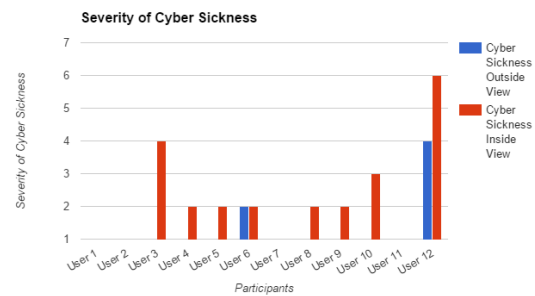


Figure 6: Degree of occurrence of symptoms of cyber sickness in participants in the study for both the augmented and virtual reality views. Everything above 5 was considered a basis for stopping the experiment.

both views intuitive and shortens the learning curve. Furthermore a smooth transition between the views ensures ease of work in extended periods of time. We also take full advantage of the passthrough capabilities by introducing a "window" to the "real world", while in the first person virtual reality view, which helps to alleviate cyber sickness, disorientation and dizziness.

We also present a user study on the built proof of concept prototype for demonstrating its feasibility, which focuses on the experience of users and demonstrates the positive impact of the system on the demonstration of 3D models to people with different degrees of understanding of the technology. Additionally the combination of the two views helps users navigate the models and better judge the scale of different parts. The overall opinion of the users is that the prototype is easy to use and with a lower learning curve. A comparison of our proposed system to the state of the art is planned for the future to further verify the positive impacts of our work and also to find the weak points. There are a number of places where the system can be improved. A hand tracking system would offer much deeper sense of immersion, as well as a high level of precision. One such solution is the Sixense STEM VR. Together with a more robust set of interaction options this scheme can elevate the usefulness of our system. This can be further improved by also introducing position tracking and expanding the "window" idea, to include visualization of the user's hands.

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