FRAMEWORK FOR REVIEWING MOCKUPS IN AN IMMERSIVE ENVIRONMENT

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Abstract

The use of virtual reality and immersive projection display (IPD) systems in the Architecture, Engineering, and Construction (AEC) industry is becoming a more viable option for traditional design review tasks. A Federal Courtroom mockup begins with the traditional design process and commences with a full review in a physical mockup. These physical mockups are typically made of plywood and housed at an off site warehouse. In some instances full scale mockups including finish materials are constructed. This research investigates the potential use of a virtual mockup to replace or augment the physical mockups. A virtual mockup was developed for a courthouse project and twenty professionals from the owner, end users, and contractor reviewed the mockup in a large display system. Surveys were used to identify criteria that judges, their staffs, and design and construction professionals perceive are the most important aspects of the design review process and which of these aspects can be assisted by using a virtual mockup. We found that virtual mockups can provide a viable avenue for reviewing project sight lines.

Keywords

Virtual Reality, Immersive Projection Displays (IPD), Courtroom, 3D CAD

1. INTRODUCTION

The motivation behind this research was to determine a better process for analyzing the design and mockup reviews to decrease the time and money spent by the project team while increasing the review quality. The current design and mockup review processes for Federal Courtrooms has worked well, but could be improved by defining a systematic review process. This research was also driven by the greater applicability and deployability of virtual facility prototypes for use in the AEC industry. The General Services Administration (GSA) had previously experimented on using virtual mockups on a courthouse in Mississippi, USA (Majumdar, et al. 2006). Jacobs Engineering and GSA saw the potential of using virtual mockups to assist in the design and construction on a similar Federal Courthouse in Virginia, USA. Jacobs teamed with researchers at Penn State to test the use of virtual mockups in an immersive projection display (IPD). In previous research with IPDs the researchers first had to identify the goal of the prototype, then determine the value of the prototype. It was shown in these studies that the type of conversation that occurs in an IPD shifts from the conversation that occurs in the traditional meetings without the use of an IPD (Maldovan and Messner 2006; Gopinath 2004). By shifting the conversation to a more focused discussion, the researchers will show the increased viability of using an IPD to augment common practices.

According to the reviewers the most important aspect of the review process is to determine if there are any sight line interferences, specifically from the Judge's bench. Accordingly, the goal of this research will be to replicate the experience and show that sight lines can adequately be reviewed using an IPD. Figure 1 shows a typical courtroom layout. The courtroom is comprised of two core components, the well and the gallery or spectator seating. Included in the courtroom well are the Judge's bench, court reporters, clerks, witness stand, jury box, attorney lectern and counsel table.

1.1 Research Methodology

The first model reviewed by Jacobs and GSA personnel on the courthouse project contained avatars and initial geometry. The purpose of this model review was to determine to what level the model would need to be modified in order for the Federal Court personnel to review it in full detail. The meeting procedure started with an introduction to the ICon Lab facilities, by showing

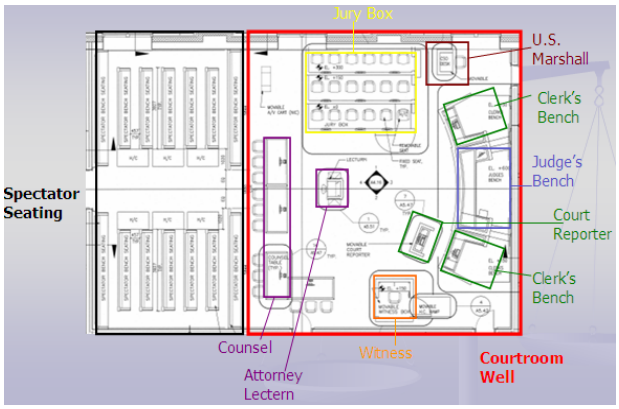

Figure 1: Typical Courtroom Layout

different types of 3D and 4D models. Following this initial introduction a pre-survey was conducted to determine initial participant perceptions related to the use of virtual reality in construction and design reviews. Additionally this survey asked the participants to rank ten criteria that physical mockups are traditionally reviewed against. These categories were: 1) Sight lines, 2) Lighting conditions, 3) ADA compliance, 4) Safety (edges, etc), 5) Security, 6) Acoustics, 7) HVAC, 8) Ergonomics, 9) Aesthetics, and 10) Millwork tollerances. The participants ranked these categories in terms of their importance and the degree of helpfulness that an immersive environment could assist in the design reviews.

Following the survey participants reviewed the VRML model that was created for the courthouse project. This model contained an avatar and predefined viewpoints. This first meeting was helpful because it aided in defining the criteria that needed to be updated on a future models for the GSA and courts representatives.

After the model review the participants were asked to complete a survey of their opinions. An identical survey ranking the importance and helpfulness was distributed.

Following the review, the surveys were coded and the model was updated based on some of the major comments that were identified in the original review. In addition, the project team was asked to note areas of the model that needed further development to make the model compare to a physical mockup with typical physical mockup reviews.

A second meeting was held one week later with project specific representatives from Jacobs, GSA, and the Federal Courts. This meeting was conducted in the same format as the first. Between the two meetings, based on the comments from the first meeting, greater functionality was added to the VRML model. The second model incorporated more interactivity. Participants now had the ability to turn on and off building components including walls, ceilings, and chairs. In addition, more avatars and linked view points were added at more strategic locations throughout the model. These avatars could also be turned on and off for greater ease of review. Views representing security cameras were also placed into the updated model.

Figure 2 shows various screen shots of the VRML model.

The second review ran similar to the first and helped to further identify criteria that would be important for a full mockup review by the Federal Courts.

2. THE PHYSICAL MOCKUP PROCESS

According to a report developed for a new Federal Courthouse, the courtroom mockup was to be a "working tool" used by different users to review configurations and functionality of the design (Stern, 2004). The review was used to test sight lines, furniture configurations, jury box location, well arrangement, public seating quantities, the bench design, and the integration of technology in the courtroom (Stern, 2004). The physical mockup review consisted of one day for review, one day for adjustments/ reconstruction based on previous days comments, and two to three day open review for court staff.

2.1 Traditional Physical Mockups

Typically, full finish material judge bench mockups are completed after the original plywood design is reviewed. Traditionally, these plywood mockups are not successful at dictating chamber lighting requirements or finish material tolerances (and properties) and aesthetics. Where the physical mockup is successful is in providing tangible objects for courtroom reviewer to touch and see (which is something they have gotten used to). Categories such as sight lines, room security, space layout are easily discernable with these plywood mockups. Essentially a physical plywood mockup may be successful at identifying sight line issues for a higher

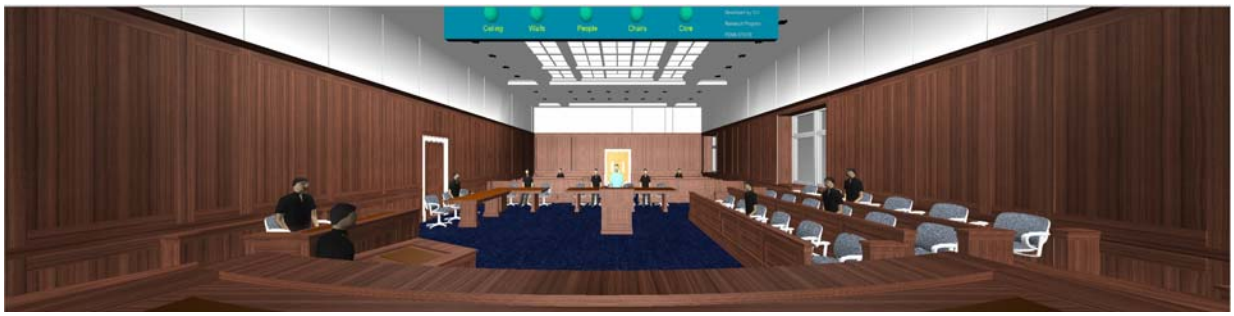
Figure 2a: VRML Models View from Judge's eyes

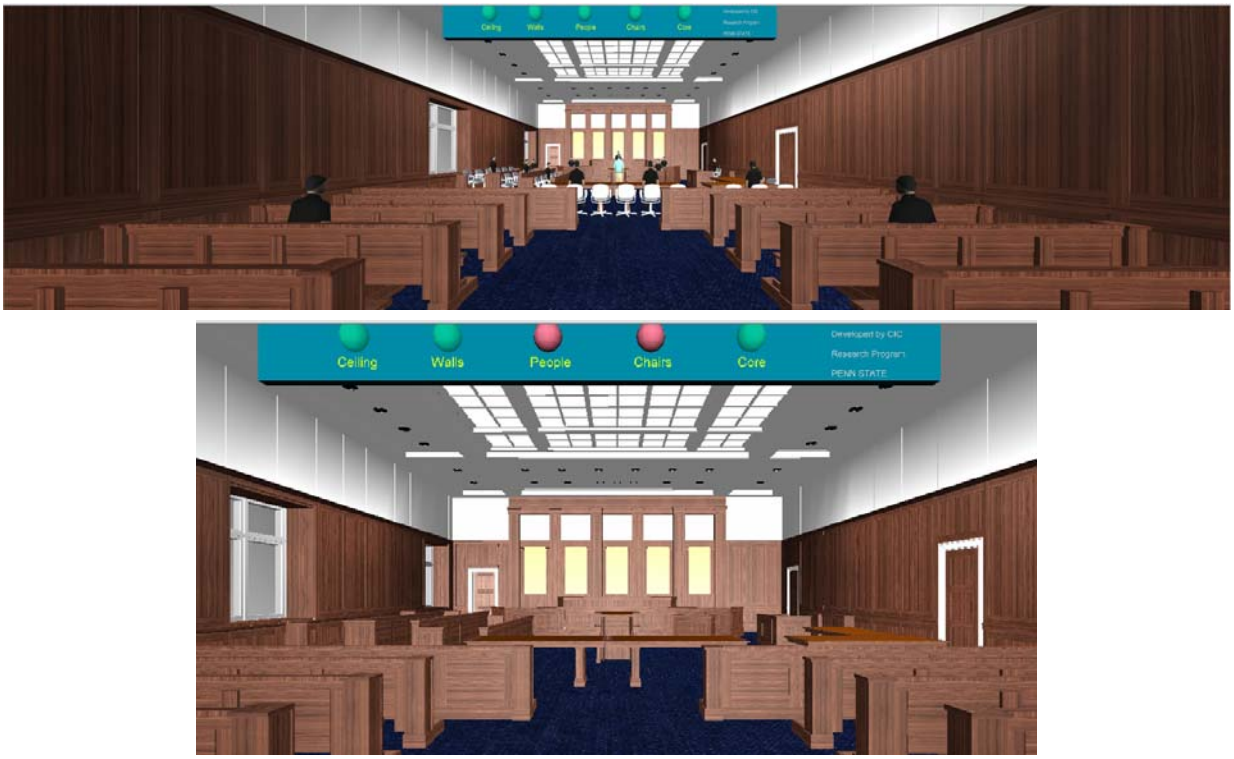

Figure 2b, c: Middle- View upon entering courtroom; Bottom- Detail of the Control Panel with People and Chairs turned off)

level judge, but other courtrooms (ex. divorce court) may still have the sight line issues, because the space was never physically mocked up.

These physical prototypes can be used to test different design options. In the case of a full finish mockup, the options will need to be fabricated before hand and reused or modified for final construction. In addition, these physical mockups give the project team the ability to visualize quality and constructability issues prior to the final product(s) being installed (Gopinath 2004). These physical mockups can be tested based on design integrity and ergonomics.

Another more crude variant of the full finish mockup is a simple plywood mockup. These mockups are reviewed according to the same criteria as the full finish mockups, but are traditionally done earlier in the project so that major sight line and design issues can be resolved. These plywood mockups are traditionally built at an off-site warehouse rented by either the construction manager or the owner.

3. THE VIRTUAL MOCKUP PROCESS

A virtual mockup is defined as a digitally rendered three dimensional model that can be used to review design aspects of a physical space. Using two dimensional schematics and shop drawings a three dimensional rendered model can be created to represent the physical space. In previous studies virtual prototypes have been defined as "a computer based simulation of a system or subsystem with a degree of functional realism comparable to a physical prototype (Gopinath 2004, Shaaf 1997). Much like physical mockups (prototypes), virtual prototypes can respond much like their physical counterparts (Gopinath 2004). Virtual prototypes also provide a degree of functionality as they can further degrees of interactivity like, multiple viewpoints, the ability to zoom in and out, the ability to turn on and off different components (Gopinath 2004).

It has also been noted that virtual prototyping and 3D modelling is a means of rapidly developing designs (Gopinath 2004, Shaff 1997). This ability to rapidly develop and modify designs makes the use of virtual prototyping more alluring. According to Issa, 2003, participants should be able to virtually test a project prior to construction, as well as the ability to test different alternatives. Walkthroughs are also used to solve problems in early stages (Issa, 2003).

3.1 The Model

The virtual model for the courthouse project was created using 2D drawings from the project architect and 3D drawings produced by the construction manager. A Bentley Tri-Forma Model was translated into .dwg format so that further textures could be applied using 3D Studio Max. Once textures were applied, to give the model a more realistic look, it was exported to VRML format. The VRML format allowed the research team to add further interactivity to the model. This interactivity included a control panel where participants could turn on and off layers and avatars located in the model, as well as the addition of defined viewpoints located at key sight line locations. Lights were also added to make the model more realistic. Construction of this model took approximately 100 hours for Jacobs' modelers and 24 hours for Penn State modelers to complete. It took

approximately three hours to finalize the VRML coding on the model.

3.2 The Display Media

For this case study, the immersive display system used was housed in the Immersive Construction (ICon) Lab. The display was developed with off the shelf components including the use of a three screen passive stereoscopic display system. With polarized glasses, (horizontally and vertically polarized filters), six high lumen output digital projectors, and a high end computer system, the ICon Lab produces an environment that simulates real world spaces at full scale. The three, six foot high by eight foot wide screens are set at 135 degrees from each other to provide a panoramic virtual reality environment. Figure 3 shows a rendering of Penn State's ICon Lab.

Figure 3: Rendering of the ICon Lab

The three screen system lends itself to versatility as multiple items can be displayed simulatenously. For design reviews, all three screens are used to display one model, allowing each audience member to get the feeling of immersion within the space. In other scenarios, such as schedule reviews, the display system can be used as a multimedia display where two screens show a 3D model and the third screen displays the schedule information.

4. CASE STUDY

Besides students in architecture, engineering, and construction, construction project teams have seen benefits to using these spaces. Previous research has found that the use of large scale visualization systems in meetings help display a variety of information simultaneously. This reduces a project manager's reliance on multiple paper documents, which may be hard for all participants to follow. According to (Liston, 2000; Garcia, et al. 2003) initial case studies where large scale visualization systems were used in project meetings, they believe that project teams perform more meaningful tasks. This visual interaction with project information helps to support decision making tasks (Liston, 2000). Previous studies in which researchers evaluated the potential value of immersive display systems have illustrated improvements in the communication process and decisions made by the team when using large format or immersive virtual environments (Liston, 2000; Garcia, et al. 2003; Yeraptathruni, 2004; Gopinath, 2004). The value illustrated by these IPDs included the ability for better communication between the team members, improved visualization of the design and construction process, and an improved sense of scale.

The main focus of this research was to identify attributes of existing design review meetings that are already occuring and integrate these characteristics into virtual mockup review meetings in an immersive environment.

4.1 Results and Observations

In both meetings, survey results showed that the top categories in terms of importance were: 1. Sight lines [6.95], 2. Aesthetics [5.92], 3. Lighting [5.84], 4. Security [5.81], 5. Ergonomics [5.45]. In addition the top categories for which VFPs can help are ranked: 1. Sight lines [2.95], 2. Aesthetics [2.73], 3. Security [2.53], 4. Lighting [2.47], 5. Ergonomics [2.39]. It is noted that these top five categories are the same for both importance and helpfulness. Therefore, it is inferred that VFPs should be able to contribute to the categories that are most important in courtroom mock up reviews. These five categories are further labeled as Key Categories.

Table 1 shows the ranking of these criteria.

Table 1: Survey Criteria Ranking

Importance			VFPs can Help	
	Score			Score
1. Sightlines	6.95		1. Sightlines	2.95
2. Aesthetics	5.92		2. Aesthetics	2.73
3. Lighting	5.84		3. Security	2.53
4. Security	5.81		4. Lighting	2.47
5. Ergonomics	5.45		5. Ergonomics	2.39
*on a scale of 1-7			** on a scale of 1-3	

It was also noted that after seeing the model in the VFP the importance across the categories was on average 0.35 less. Sight lines remained the same and Aesthetics went up 0.17. The greatest decrease was seen in Acoustics (-1.26) and the key category to see a greatest decrease was lighting (-0.53).

In terms of helping, the overall trend was an increase of 0.11 across all categories, with the greatest gain (+0.42) seen in Security. The only decreases were seen in Acoustics (-0.32) and Millwork (-0.06). The only key category to see a decrease was Ergonomics (-0.05).

Figure 4 shows the virtual mockup reivew in the ICon Lab.

Figure 4: Review Meeting in ICon Lab

5. CONCLUSIONS

The question of why physical plywood mockups are still being constructed in lieu of more progressive design review techniques is posed. If the main categories that are reviewed during the physical mockup review can be replicated in a non-traditional (virtual) setting at a lesser cost, and lesser time, and more design options, and more courtroom options, why then should virtual mockups not be implemented as an alternative or additive to traditional design/ mockup review procedures. This study proposes using IPDs and VR to aid in courtroom design and mockup reviews.

The results of this project will benefit Jacobs/ GSA by identifying opportunities to improve the mockup review process, via the traditional method and the potential for using immersive display systems. This project will define an implementation plan for integrating immersive display system mockup reviews into standard practice if the meetings held in immersive display system are successful. By observing the process and quantifying success, a development plan will be produced to guide future uses of IPDs for design and mockup reviews.

6. FUTURE RESEARCH

The goal of this and furture research is to improve current mockup review procedures and define a detailed process for reviewing mockups in a virtual and scenarios. The goal of this research is to find out to what level virtual models will assist in the mockup review process and to determine if they are a viable option to assist or completely make obsolete the current mockup procedure. An analysis of the benefits associated with virtual facility prototypes will be completed to determine to what level, if any virtual mockup can assist the design/ mockup review process. Further reviews in an IPD are planned for the Federal Courts to further test the applicability of using virtual reality.

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