AC 2009-906: DESIGN VISUALIZATION AND SERVICE LEARNING: USING PHOTOREALISTIC COMPUTER RENDERING TO SUPPORT A THIRD-WORLD COMMUNITY-DEVELOPMENT PROJECT

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Introduction

Computer rendering has evolved to a point where the ability to generate photorealistic images is a standard feature in most CAD applications. The objective of photorealistic rendering is to “generate images from computer modeled scenes with an image quality as close to real life as possible” ^[1]. The origins of computer rendering are rooted in technological developments that are nearly a half-century old. However, more recent developments in photorealistic rendering applications and in the processing power available in desktop and laptop computers have made highly realistic design visualization accessible for most users of applications with 3D modeling capabilities.

The application of advanced digital rendering technologies is commonly associated with computer gaming and high-profile Hollywood digital-animation productions. However, the photorealistic rendering can also be utilized as part of strategy developed to respond to complex communication problems. The communication potential of photorealistic rendering played a key role supporting a recent project involving the development of physical and virtual prototypes for third-world community structures. This project, which was initially undertaken to provide assistance to a village in a remote area of rural Uganda, has developed into a proposal for school and community structures that could potentially be replicated in multiple locations and accommodate a range of environmental conditions. The project was influenced by the priority the project architects placed on developing a culturally responsive solution while accommodating extensive economic and technical constraints including designing a structure that facilitated participation by members of the local population in the construction process.

Project Background

The project team was initially assembled with practitioners, faculty and students in the UK, with all professional services provided on a pro-bono basis. Christopher Hill, principal with Linedota Architects in London and a faculty member in architecture at the University of Nottingham, was the project leader. The technical parameters established for the project included the following:

- To build for 30% of the cost of conventional construction in rural Uganda.
- To build in 30% of the time required with conventional construction in rural Uganda.
- To be carbon neutral or negative, and environmentally sustainable with potential to reuse or recycle 100% of the materials.
- To be safer than common construction practices in rural Uganda under earthquake and wind load conditions.

The project began with a 12-day field visit to Uganda. Critical aspects of the project included consultation with the local authorities, politicians, personalization of the school and clinic by the building users, and development of a master plan for the village. Activities included community focus group and mapping sessions. Drawing workshops for the village children were also conducted with the intention of integrating the children's artwork into the project design. While the physical output of these activities was important, gaining an understanding of the social interactions (i.e. identity and social "performances") was deemed critical to developing a proposal that was responsive to the needs of the community. Investigations were also conducted into local archetypes, construction methodologies and materials, economic considerations, local construction skills and capabilities, and climactic, geological and environmental conditions.

Assessments of the materials and construction processes commonly used in rural Uganda found that the construction methods were largely dependent on the size of the structure. A form of adobe construction was typically used for small structures and usually required approximately two months to complete. These structures were found to be subject to several common failures such as wall and roof erosion and roof leakage. Larger structures typically use mud brick construction. The walls were constructed of locally-produced hand-made mud brick using wide steel-reinforced mortar bed joints in order to accommodate the large variations in brick size. The brick varied extensively in quality and the strength and durability of the brick was determined to be very unpredictable. The roofs were usually double-pitched, constructed with 3" profiled metal sheet nailed directly to the timber for roofing material. These structures commonly had problems associated with internal overheating and cracking in the walls and floors from seismic activity, poor quality foundations, and inconsistent quality of the bricks.

Design Response

Based on the findings of the field assessment and the project parameters the project designers concluded that poor quality of many building materials, lengthy construction times, and the presence of seismic activity in many of the potential project sites made the use of conventional structures and materials was impractical. However, a decision to pursue alternative construction strategies posed additional challenges. Cost considerations required that the construction work be undertaken by local labor. However, assessment of local conditions revealed that in addition to there being a scarcity of skilled labor in the rural regions, the skill-set of laborers with construction experience was largely limited to conventional building methods. Therefore, it was concluded that the construction processes and procedures would have to include unskilled laborers, including laborers with little or no construction experience, and that the use of alternative construction would require strategies that could be easily learned and adapted by the residents.

The project logistics and economic constraints also necessitated the use of materials that would be commonly available in the rural regions. More indigenous materials used in conventional construction such as brick, adobe, and wood were ruled out early in the design process due to the poor quality control, durability limitations, and vulnerability to environmental conditions. To meet the project parameters the project designers pursued a strategy which relied on the non-locally produced yet locally available manufactured materials that responded to the economic, environmental, and quality control issues of the project. These materials included steel tubing,

profiled sheet metal (similar to what was used in some conventional building in the region), exterior-grade plywood, and locally grown treated logs. The structure was designed to primarily utilize bolted connections as it was determined that local welding practices were found to be often imprecise and unreliable. The proposal also utilized floor structures independent from the enclosure and a framing design with framing that would be more suitable for seismic conditions. The resulting proposal utilized a built form that was dramatically different from that commonly found in the region (Fig. 1).

While the materials were not unfamiliar to the community members, it was anticipated that the unconventional form of the structure would meet some resistance from the local population, particularly since the legacy of colonialism still raises suspicions in many areas of the undeveloped world when confronted with what may be perceived as the decisions which supplant local traditions. Additionally, since the project logistics and cost parameters precluded the use of formal site supervision from the architects, engineers, or construction managers, the ability to clearly communicate critical information related to construction and assembly processes to a broad range of constituencies would be an essential component in the project's success. This was further complicated by several factors, including language barriers and the requirement that the structures be able to be adapted to a variety of locations with potentially diverse environmental conditions including variations in topography, rainfall levels, and seismic conditions. The variety of potential sites meant the project documentation would be able to be utilized by individuals with diverse dialects and varied literacy levels.

Consequently, it was determined that a graphic communication strategy would be an integral project, developed in parallel with the architectural and engineering design work. As the project was based on services rendered on a pro-bono basis, including students in the project was determined as a viable option that would provide a unique service learning opportunity that would provide substantial benefits to the students as well as the project principles and clients. Service-learning has been defined as “a hands-on learning approach in which students achieve academic objectives in a credit-bearing course by meeting real community needs”^[2], and in comparison with other academic fields, technical and engineering programs have been slower to integrate service learning into coursework^[2]. According to Jacoby^[3] service-learning provides mutual benefits for students, faculty, and the university, as well to the organization or community served. For faculty in programs emphasizing graphics, design, and visualization, the role of graphics as a communication medium can provide unique opportunities to integrate service learning opportunities into coursework. Specifically, course content related to technologies such as photorealistic computer rendering, which is widely used as a visualization tool in nearly all design professions, can be utilized as a means of connecting coursework and real-world constituencies by structuring activities to exploit the visualization tool's communicative potential in cases where more conventional graphic techniques be ineffective. Following the successful completion of physical prototypes by students in the UK, the design visualization tasks were assigned to a team of four students at Bowling Green State University in the United States under the supervision of Dr. Stan Guidera, an architect and member of the university's architecture faculty.

Students were recruited to contribute to the project on a volunteer basis, with selection based on their skill sets with the requisite digital technologies. The relevant communication requirements

were divided into two primary categories: first, communication of the design proposal in terms of its cultural and sociological acceptance by members of the community and secondly, communication related to the assembly, particularly in terms of overcoming both language and technological barriers. In terms of the technical aspects of assembling and constructing the buildings, it was assumed that the community members charged with supervising as well as those charged with constructing the assembly of the structures would have limited access to computers and internet access. Based on the potential barriers raised by the previously noted variations in language and literacy levels, it was determined that communication of the design and construction intent would have to rely on printed graphics with a minimal reliance on text. It was also determined that many people involved with constructing the projects would be involved in building for the first time and would have little or no experience in interpreting conventional orthographic views. As a result, highly representational and realistic renderings were determined to have the greatest potential for effective communication with the target audience.

More importantly, however, communication of design intent was determined to rely on the potential for the users to make a clear and understandable connection between the documentation of the proposals and how it was to be situated within the context of the local cultural as well as physical environment. Therefore, in addition to assisting with construction documentation, the use of highly realistic representations was deemed a priority in order to convince local population that the proposed design concepts were compatible with local preferences. Therefore, a two-pronged strategy was developed that would use digitally generated photorealistic graphics and images to attempt to address the larger issue of securing cultural “buy-in” for the project among the local constituencies and for producing documentation that could assist in overcoming the technical limitations of the users.

Strategies for representation

The project proposals included both the individual structures as well as a master plan for a community complex which would involve variations of the proposed structure. Students were charged with developing renderings of the master plan options as well as renderings integrating images of villagers with the proposed structures and master plans. Simultaneously, images of construction sequences were also being developed. By necessity, the working assumption was that there would be no reliance on text and verbal communication. Rather, communication would rely entirely on 2D documentation of 3D representations, with the intention of providing supplemental video and animation support where accessible.

Cultural Connection: Securing community “buy-in” on the building form and master plan

A key strategy in communicating with the constituencies in the project location involved representing the proposal in a convincing way in the native landscape. Therefore the use of integrating computer renderings with actual site photographs was utilized. Students relied extensively on 3DS Max for rendering and Photoshop for image editing. Project documentation used to gain acceptance of the form focused on integrating images of local villagers at the initial project site composited into computer renderings (Fig. 2) as well as computer renderings composited into views of the local landscape (Fig. 3 and 4). Additionally, the computer

renderings showed the end-walls decorated with artwork created by the village children during the on-site workshops (Fig. 3 and 4).

The representations of a proposed master plan for the community using various versions of the proposed structure were more problematic in that a conventional orthographic site plan was not readily understood by the villagers (Fig. 5). While it was determined that a perspective view would be more effective, there were no “birds-eye” images that were available for compositing. Results of initial attempts to produce perspectives with composited landscape elements were determined to be unacceptable in terms of their visual quality, primarily due to the viewing angles of the available site photographs. Therefore, renderings using computer modeled trees proved to be the most effective strategy even though this resulted in significantly longer rendering times than if composited landscape was used. In order to make a computer generated site perspective more effective, the materials in the 3DS Max master plan file utilized bit-maps sampled from the photographs of the site (Fig. 6).

Strategies for construction representations

The strategy for documenting the construction details and sequences relied on renderings generated directly from Rhino Render in Rhino 3D, a NURBS-based modeling application. The construction documentation, which is under ongoing development, has made extensive use of cut-away rendering and series-rendering that showed step-by-step processes to be followed in assembling the structures (Figure 7, 8, and 9). In some cases the step-by-step renderings were generated using computer animation of the assembly process, and then saving the animation as a series of .jpg files with the animation sequence set to render only every three or four frames. Additionally, some images in the documentation were expanded to include minimal text which could be more quickly modified to accommodate language variations, particularly where the content was directed towards someone functioning as a local project supervisor. However, the text was intentionally secondary to the graphics (Fig. 10).

Summary.

The project has proved to be a very effective way for students to apply current skills and develop new skills using advanced rendering processes and technologies. Several students have included work produced for this project in their graduate application portfolios, and all have highlighted their participation and contribution to this project on resumes and job applications. However, the best indicator of the success of the project in utilizing photorealistic rendering as a communication tool can be found in a reference to the success of the digital imagery in gaining acceptance for the proposal among the villagers. After the project leader for the village had shown other villagers images and photographs of the prototype, he reported that he received some encouraging and excited comments back. One of the comments was particularly significant:

‘...people will come from all over the world to our village to see these buildings...’

Bibliography

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3. Jacoby, B. (1996). Service-learning in today's higher education. *Service-learning in higher education*, 53-91. San Francisco: Jossey-Bass.

Figure 1. 5-bay and 7 bay versions of final structure (Cut-away view)

Figure 2. Composite rendering (above) and photograph composited with rendering (below, left and right)

Figure 3. Composite rendering merging computer model with site.

Figure 4. Composite rendering merging computer model with site.

Figure 5. Master plan orthographic drawing

Figure 6. Master plan computer generated site perspective.

Figure 7. Truss and truss connection renderings

Figure 8. Footing connection rendering

Figure 9. Cut-away view rendering.

Figure 10. Cut-away view rendering with annotation.