Utilization of Animations for Construction Visualization

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Abstract

Design and construction of residential and commercial structures relies heavily on construction documentation to convey not only form and function, but also to aid in the estimation and marketing of the structure. If done with traditional methods, residential design and construction requires several people and countless hours to gather the data in useful forms. The traditional documents that are necessary for the construction processes are the estimate, bill of material and construction documents or working drawings. Each process requires each person to interpret the construction documents that inevitable incorporates error and material waste into the construction process. These documents are the initial start to a larger process. Visualization of the entire process and individual assemblies of materials has become a standard requirement for individuals in the construction industry. The education needed for construction is gathered by hands on experience and can take several years for the individual to obtain. Many AEC firms do not have the time to train carpenters, subcontractors, or superintendents how construction assembly processes come together. Technology is providing marketing alternatives such as three-dimensional models for visualization, simulation and spatial analysis. Technology has also provided a means to deliver this information effectively- the Internet. This paper will discuss on-line construction animations of assembled construction processes and the results obtained from student testing of traditional 2D data, 3D renderings, and 3D animations delivered over the Internet.

Keywords: *3D Model, Spatial Design, Construction, Educational Spatial Visualization, AEC Industry*

1. INTRODUCTION

The art of constructing structures is a continuous educational process. There has always been difficulty associated with training Architectural, Engineering, Construction and Graphic Design students, along with professionals in the field how to assemble the pieces of the structure. Construction practices without hands on experience or previous training is extremely difficult to visualize individual construction processes- let alone trying to put together the entire structure. Currently, the precedence for this training is with the use of textbooks containing two-dimensional drawings. It is estimated that 90% of the population in the world have trouble visualizing these 2D Multiview illustrations as three-dimensional objects. Therefore, they cannot adequately learn the how the parts of the structure are assembled. The problem is that most students and professionals are afraid of creating construction documents utilizing 3D Modeling. "It's a short jump-not a leap of faith- from two dimensions to three dimensions" Matthews [1]. What graphical communication methods can be developed to better introduce this knowledge to these students? Are three-dimensional models a better, more efficient way to communicate this knowledge than two-dimensional media? If so, how can we best use today's three-dimensional technology to better facilitate this learning? According to Giambruno [2], "The implementation and utilization of 3D models, especially architectural, had become significantly easier and more efficient to construct." Is there something beyond 3D models that can be utilized for better understanding of construction assemblies? Fallon [3] states that the benefits of intelligent modeling approach to the AEC industry are increased productivity, reduced cycle time, better work flow amongst group members, and life cycle applications. These are important concepts and valuable concepts to people that are concerned with project management; but unless the user has a firm grasp on the entire construction process, only a few of these concepts will be utilized to there full potential.

These questions were the premise behind the project and initial survey- a project designed for a senior level design course that required the students to create a graphical library of assembly construction procedures for the AEC Industry. How were they to test whether the assemblies were actually beneficial was the problem the group had to solve. Creating the 2D construction documents, 3D pictorial illustrations, and 3D animations was not that challenging for a student in Computer Graphics. The assemblies were standardized so they could apply to several building types. The assembly information system was web based so it would allow users to better visualize and comprehend complex building techniques with little or no knowledge and or previous training. It did not however allow the test subjects to take the survey anywhere they wanted due to specific software used in the survey.

Previously, the use of two-dimensional drawings and textbooks were the primary source of such information when on-site training is unavailable. On-Site training can be difficult due to the timeline schedule of the construction process. So how could the education be facilitated without impeding the buildings construction schedule? The information would be made available through a database-driven website that can be accessed from any computer, laptop, or PDA available.

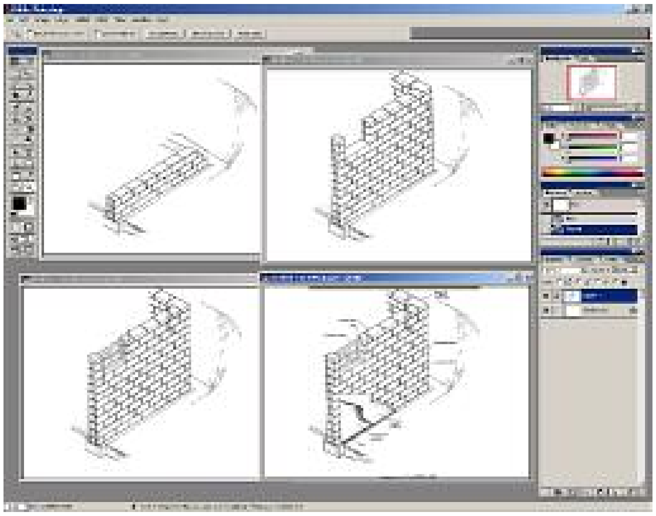

Figure 1- Photoshop Storyboards

The project was undertaken by a group of students in a senior level course at Purdue University. They came up with most of the information and graphics for the survey with a strict guidelines defined before the project began. The entire process covered a 16-week semester.

First, an initial process or flow chart was laid out. This included a basic workflow and how tasks would be divided between members. As the project parameters became clearer, the process was modified, streamlined, and broken into pre-production, production, and post-production cycles.

The pre-production included picking construction details and creating storyboards. The production stage included modeling, animating and rendering. And the post-production stage included compositing and web implementation.

Also, early on, the team developed a file system to help keep track of the many files. The figured out that multiple people would need access to the information and a well organized naming convention allowed easy access for all group members to all files, as they were being created or modified. The file organization included folders for animation, documentation, and research with each having the appropriate sub-categories within. This file structure was set up to help speed and smooth the process.

2. PRE-PRODUCTION

The first item of concern was the construction details that were going to be included in the initial release of the website. Initially, The group was given 28 different pictorial representations to use as the basis for a series of animations. After modifying the project to include Cult3D we were empowered to cut the number down. Fifteen details would be included on the initial website, which was decided on by the group. The final fifteen were chosen from the original 28 in an attempt to have a diverse representation of construction practices and complexity. The group wanted to have as diverse mix of construction processes in order to adequately find where animation was needed most for visualization. Once the construction details were finalized, storyboards for each had to be created. For each detail pictorial drawings were obtained from "Wood Frame House Construction" to use as a basis for the models. Therefore, these diagrams were used to expedite the storyboard process. This was accomplished by digitizing the pictorial drawings using a scanner. The scans were then imported into Adobe Photoshop and manipulated into assembly steps. (Fig 1)

3. PRODUCTION

The production cycle of the process included modeling, animating, lighting, materials, and rendering. All of this was done in 3D Studio Max. 3D Studio Max was used because the team had proficient knowledge by the group members and because it interfaced nicely with Cult3D. The first thing the team did was model the scenes (Fig. 2)

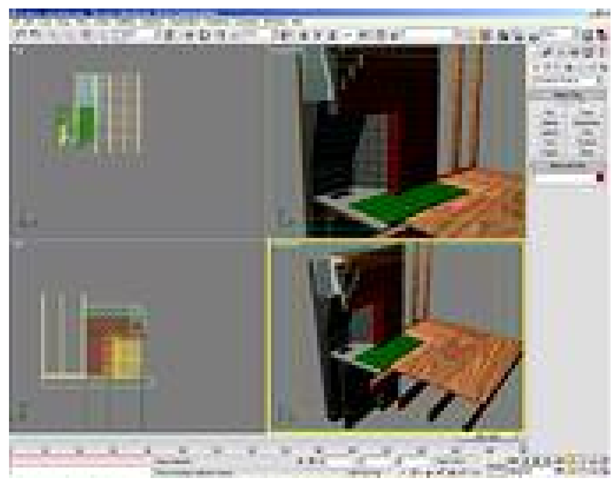

Figure 2- Modeling

As the modeling was being completed, the models were exported out of 3D Studio Max into Cult3D so that the production in Cult3D could begin. Within Cult3D events were setup to allow the user to manipulate to models with the click of a mouse. Once events were setup, Internet ready files were exported from Cult3D. Also, as the models were being produced, a parts library of the individual pieces was developed. Last the details were animated according to the correct assembled process, textured with realistic material library of bitmaps, lighted according to a pre-defined lighting scheme developed by Professor Scott Meador of Purdue University, and rendered frame by frame to complete the entire animation. (Fig 3)

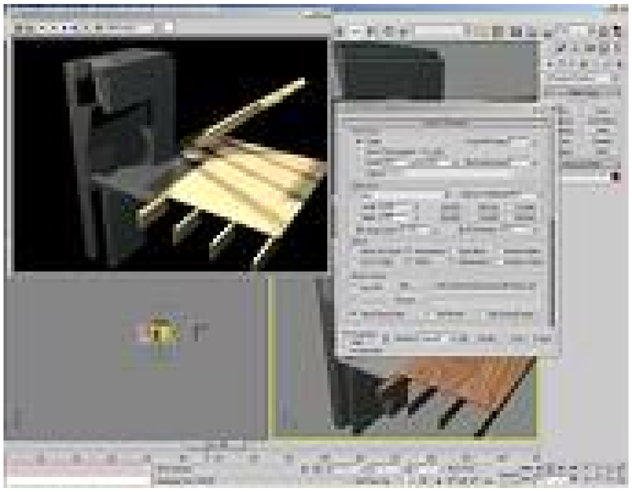

Figure 3- Lighting Schematic

4. POST PRODUCTION

The first step in the post-production process was to add labels to the already rendered frames. The purpose of these labels was to inform the user of the individual piece names as the construction detail was built. Once the label frames were completed, all of the labeled frames along with the rendered targa sequences were imported into Adobe Premiere. Here the timing was manipulated to produce a final cut of the animation. This final cut was then outputted as an uncompressed AVI and brought into Adobe After Effects for finishing touches (Fig. 4). Here color, brightness, and contrast were brought to optimal levels. Also the final render for the web was produced here. The final animations ended up staying at full resolution, 640x480, yet were under 1MB.

Figure 3- Lighting & Materials

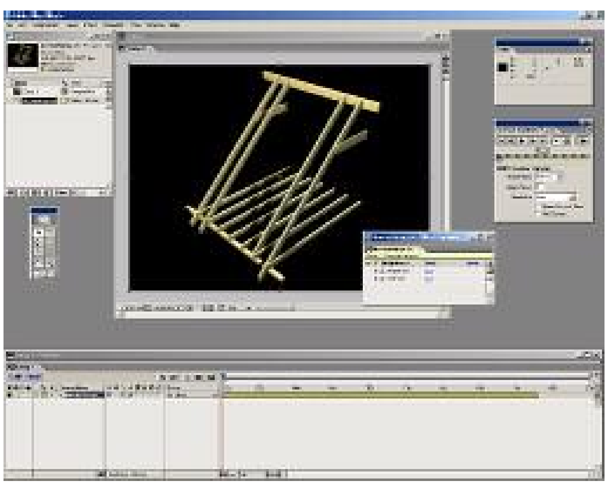

Figure 4- AVI Composition

The final step of the post-production stage and project was to implement these animations and Cult3D models into a database driven web page.

The web implementation process used a dynamic database. The database was written using ASP (Active Server Pages). ASP used a Microsoft Access database to generate the web page. The web page was written in HTML that was generated within the ASP code. The files were placed in a folder on a server, which was then referenced within the Access database. When a file was added to the database table, the web page generated the file, whether it was an AVI, Cult3D, or a jpeg. Anything added to the table in the correct column was automatically placed on the web page with the correct links. The Cult files are encoded into a frame on the web page. The AVI files are opened with Windows Media Player.

5. SURVEY SETUP

In order to evaluate the effectiveness of the group's product, a survey was created. This survey compared the ability of end-users to remember construction assemblies after seeing a diagram versus watching an animation. This test was done on-line, using the Test Pilot software.

There were two test versions. Users of both tests were first asked a series of routine questions. These questions were of a demographic nature. After five of these warm-up questions, they were given six actual test questions. They were asked first to study a pictorial diagram of a construction assembly. These diagrams were our team's basis for what is "normally" shown to students learning construction practices. They were also the basis from which all of our animations were made. After studying the diagram, the user was shown a three-dimensional model of the diagram they had just seen and asked whether or not it was correct. These models were done using the Cult3D that could be rotated, zoomed, disassembled, and moved around in any way the user desired. The Cult3D software provided the best simulation of real-life that could be attained in a computer test environment. After the test subjects had gone through three diagrams and Cult models, they were switched to animations. The users were asked to study the animation provided, watching it as many times as they liked. When finished, as before, a Cult3D model of the animation they had been shown was displayed. They were then asked to state whether or not that model was built correctly.

The second test was the same layout as the first test only with different questions. For this test, the subjects of the questions were reversed. The diagrams used in this test were pictorial views of the animations shown in the first test. The same was true for the second three questions; the movies shown were animations of the three diagrams shown in the first test. This gave results for the analysis of six construction assemblies with diagram data and animation data for each. Both tests had two additional questions at the end of the test. These were to survey the user's preference and opinion towards the animations versus the pictorial drawings.

5.1 Results

For this test to be effective, it was critical that all media types between each survey be consistent with each other. The animation, diagram, and Cult3D model all had to be constructed with precision. The only exception was for those Cult models that were intentionally modeled wrong. During the administration of

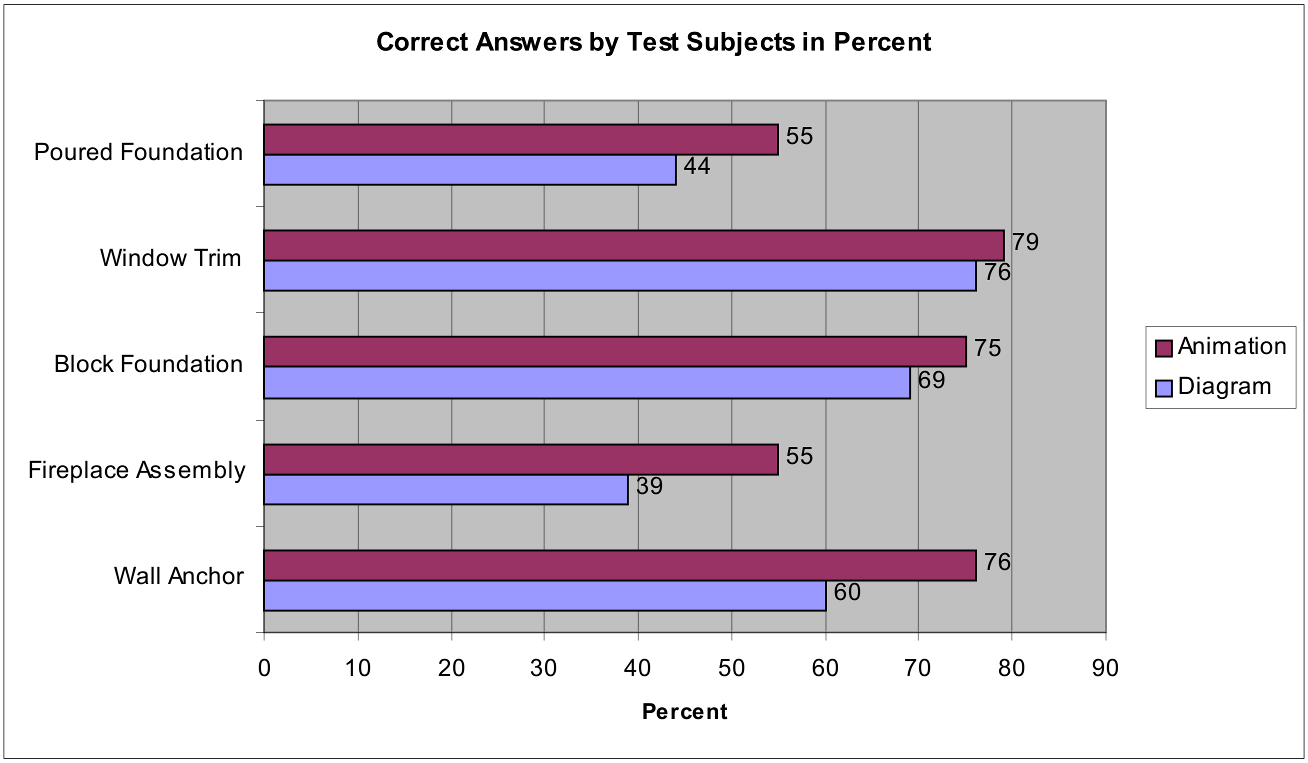

Table 1- % of Correct Answers

the test, it was realized that an error in one of the animations had been missed. The diagram and the Cult model for the header assembly both had a double top plate on the wall, but the animation did not. There was no way to fix this error during the test or alter the data after the test to correct for this mistake, so that question was thrown out.

The target sample for the surveys was 40 people, 20 for each survey. The turnout for the survey was much higher than expected, resulting in a sample size of 101 people. This should give the final data more validity, even with the exclusion of the one question. A total of 505 data points were collected.

It was found that the animations caused an average of a 21.1% increase in comprehension over the diagrams- both 2D and 3D illustrations. It was also observed that the animation had a more positive effect on those assemblies that were particularly complex. For example, the masonry fireplace model, which was the most complex assembly, had a 16% increase in correct answers with the animation. However, with the window trim assembly, which is a relatively simple model, there was only a 3.9% improvement with the animations. Correct answers with this model were high to begin with, having 76% of the test recipients answering correctly with diagrams, and 79% answering correctly with animations.

The final two questions provided very encouraging data. When users were asked, "Do you feel that it was easier to learn the construction assembly methods from looking at the diagram or watching the movie," 91% responded that it was easier to learn from the movie. When users were asked, "If you were learning this material in a classroom, do you think the animation would help better facilitate your understanding of the material," all 101 people, 100% of the respondents, answered YES.

5.2 Audience

The audience expected to utilize the educational tool is that of students, apprentice carpenters, and industry professionals. This group of people stands to benefit greatly from the product and its practices.

5.2.1 Students

The students in the audience will be those who are currently attending a college or university and are focusing their studies on Civil Engineering, Construction Management Engineering and Building Construction Management Technology. Only a small percentage of students get the opportunity to visit work on an actual job site through coops and internships. This leaves a large number of students that will receive a college degree without ever gaining on-the-job training or real world experience. This new tool will benefit them by providing an opportunity in the virtual world to acquire knowledge of the building construction methods, which will make them more prepared to work in industry.

5.2.2 Industrial Professionals

The professional audience will be composed of individuals that are currently employed in the building construction industry.

There will be some individuals that have had formal training already, along with others that are new to the industry and need more instruction. Other professionals in the industry may use our product to teach building techniques and practices to non-English speaking individuals. The intended goal is to instruct construction individuals in the neighboring area and to implement the educational tool in a large city where construction practices and individuals are very diverse. The author has made several connections with construction firms in Atlanta Georgia and in the neighboring cities around Purdue University. In the case of Atlanta, they would be using the product to break the language barriers that exist in the industry both for the residential and commercial areas of construction.

6. CONCLUSIONS

The process of designing, constructing, and operating buildings is among the least computerized of all industries Laiserin [4]. According to Ethier and Ethier [5], modeling can provide us with a wide range of benefits, and deciding on which modeling package to use for the AEC industry can be challenging. It is time the AEC industry caught up with the rest of the industry. With the use of simplified graphics in the form of animations and three-dimensional interactive models- students, apprentices and professionals alike can learn building construction practices more quickly and easily. With an average information retention increase of 21.1% over the existing standard way of teaching, it is clear animations delivered of the Internet provides a more effective way of teaching assembled construction details. The era of constructing buildings with 2D Multiview documentation is declining at an extraneously slow rate. The AEC industry recognizes the importance of construction communication throughout the entire cycle of the structure. 3D modeling of that structure is the solution. Modeling relays information not only to the design area, but the estimation, scheduling, and actual construction process. These test of construction assembly processes only reassures the author's beliefs that modeling is the future in AEC construction communication and comprehension.

7. FUTURE WORK

The goal of the author is to develop several animations for both residential and commercial construction. Implement a online construction help website and test the results of the benefits of those animations. As stated in the industrial professionals, the author has made several connections of construction professionals and can utilize their workforce for testing. The author also has access to several hundred Civil Engineering, Construction Engineering Management, and Building Construction Management students at Purdue University. With the diverse data set, the results should validate the need for animated processes for construction visualization.

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Clark Cory is an Assistant Professor in the Department of Computer Graphics Technology at Purdue University in West Lafayette, Indiana. He received his Associate of Applied Science in Building Construction Management, a Bachelor of Science in Technical Graphics and a Master of Science in Education Computing from Purdue University. Clark's primary professional responsibility is undergraduate instruction in architectural and construction graphic communication and visualization. He is currently helping develop a Construction Graphics Communication specialty area within the Computer Graphics Department at Purdue. Professor Cory's areas of interest include topics on the improvement of cognitive visualization in construction using 3D models, the impact of new technology on the jobsite of construction, and smart house technology. His presentations include national and international conferences. He currently teaches courses on 3d modeling in construction, Architectural documentation, digital lighting and rendering, raster graphics, and animation. Clark has had over 20 years experience in the AEC industry with positions ranging from general laborer to project manager of 25 residential structures per year.

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