Investigation of Digital Three-Dimensional Representation: Results of a Faculty-Undergraduate Student Engagement Grant

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Introduction

The language of architecture is expressed in the drawings that are used to conceptualize structures. For students as well as professionals, design language alternates between two-dimensional (2D) and three-dimensional (3D) representations. Three-dimensional graphics is the medium most suited for use by clients while professionals are expected to switch seamlessly between 2D and 3D representations at various points during project design and execution depending on the situation. It logically follows that for students a vital part of their training is learning to work with 2D as well as 3D representations. In the Architectural Science (AS) program in the Architectural and Manufacturing Sciences (AMS) Department at Western Kentucky University (WKU) students are given a solid foundation in 2D visualization in their freshman year. In the freshman architectural drafting course AMS 163 students are introduced to orthographic and isometric projections using hand drafting tools as well as computer-aided design (CAD) software [1], while students are introduced to3D modelling the emphasis is on 2D drafting. The emphasis on 2D drafting follows through right into the senior year through a series of architectural documentation courses; AMS 263, AMS 273, AMS 363 and AMS 463 [1]. 3D modeling is taught in two courses in the curriculum; AMS 151 architectural graphics has a small portion of the course dedicated to 3D hand drawing and digital 3D visualization using SketchUP [1]. Following this course the students move to AMS 251, 3D modeling which concentrates on digital 3D tools [1]. The software taught in this course ranges from SketchUP, 3DS Max, ArchiCAD typically depending on the expertise of the faculty teaching the course. Students are expected to experiment with available 3D and rendering software to improve their skills and apply it in design studios and other subsequent courses in the curriculum.

An internal Faculty-Undergraduate Student Engagement (FUSE) grant received at WKU towards the study of tools and techniques used in creating a 3D visualization of a given structure enabled the student under the guidance of the faculty to conduct an in-depth investigation of programs and techniques used to render 3D representations. Due to limited exposure to digital 3D rendering software the student wanted to create a 3D model, and use available rendering software to create realistic imagery.

Digital Three-Dimensional Visualization

Since the inception of digital tools for architecture, the use of computer tools for the creation of architectural drawings has increased tremendously. The initial period saw the use of digital tools merely for 2D drawings, but this has since progressed to software for creation of complex 3D models and more recently towards parametric software for intelligent design. The last couple of years have seen an explosion in the creation of 3D walkthroughs, animations and “fool-the-eye composites of computer-generated images and photographs” [2].

Digital programs can work as quick tools for initial conceptual models, massing studies as well creating complex forms, understanding relationships to surrounding structures and scale-proportion studies. These tools when used appropriately create accurate plans, elevations, and

details and can generate appropriate three-dimensional drawings [2]. The use of digital media to conceive of design ideas and representation has increased tremendously and its success is attributed to speed, accuracy and resulting perfection [3].

An important and integral part of the generation/ creation of a three-dimensional model is the rendering process that the model undergoes. According to Schillaci, "to render is to represent". Representation has always been used to communicate to the masses but in the present day rendering has become a very important component of winning architectural commissions and a successful rendering should be able to catch the viewers' attention amongst all the other images [4]. Modern architectural practices produce design drawings which are then passed to either in-house or out-of-house renderers to create interesting imagery for the client. The out-of-house renderer may even be in a different continent [5].

In reviewing course catalogs of accredited programs of architecture in the region it was found that most schools of architecture at the undergraduate level have at least one if not more courses dedicated to teaching visualization, digital design and 3D modeling techniques. Schools reviewed have introductory courses in 2D and 3D CAD. In the 2D CAD courses students are typically introduced to CAD software, orthographic projections as well as creation of working drawings. In 3D CAD students are introduced to visualization techniques. Advanced courses in 3D visualization are present in the curriculum across the board where students work with software. In some scenarios 3D modeling is integrated with technical details to enhance building design. Continued development of visualization techniques is carried on in the design studios. Courses in digital design, graphic design, presentation techniques, and image manipulation have become an integral part of most curriculums. Of the programs reviewed one program had a specific course in which students were exposed to rendering and animation software [6], [7], [8], [9].

FUSE Grant

"FUSE grants at WKU are designed to support undergraduate students' intellectual development by fostering active engagement in the areas of research, creative and scholarly activities, and/or artistic performances" [10]. They are awarded to undergraduate students with good academic standing. The student undertaking this study applied for the grant during spring 2013 and was awarded the grant in May 2013. The student began working on the grant at the beginning of fall 2013 and while rendering is an aspect which can always do with more work and refinement a logical point of conclusion was reached in the beginning of December 2013.

According to Schillaci a render is the result of four steps; "(1) Data Collection and organization, (2) Three-dimensional modelling, (3) Mapping, illumination and computing and (4) Post-production" [11]. While all the four steps as outlined by Schillaci were carried out in this study, the focus was specifically on Step 3 of the render process and was conducted with an aim to experiment with available rendering software to compare the rendering programs used with respect to (1) steps required to setup the view to be rendered (ease of learning), (2) time taken to produce graphics, and (3) quality of graphics generated. Quantitative as well as qualitative data was collected from this study. Quantitative data took the form of observing and recording two of the above mentioned parameters (steps required to setup the rendering and graphic generation time) while the images generated formed the qualitative data set.

Students in the AS program in the AMS department spend their time in the design studios trying to perfect their designs till the very last hour before a presentation; as a result they have very little time to create rendered images of their 3D models which could enhance their presentation drawings. The student was keen to research this area of architectural visualization to develop and document insights which could be used by other undergraduate students to prepare basic renderings of their designs for presentations. The student aimed to describe the process involved in using the programs, difficulties encountered, and the outcomes achieved based on the images created.

Process of Study

For this study the student used SketchUP to create the 3D model. SketchUp is the most popular three-dimensional modeling software used in the world with over 30 million SketchUP activations occurring in 2011 [12]. The software is available for free download while the professional version has a cost associated with it. Students in the AS program at the University are advised to download the software in their freshman year as it serves as a good conceptual design tool. In the 2011 Design Intelligence Technology & Innovation Survey it was found that 68% of firms used SketchUP [13] which was one of the main reasons for using it for this study.

The building selected for the purpose of the study had been designed by a senior student as their capstone project. Criteria involved in selecting this building for the study were: the manageable size of the structure, as well as an opportunity to modify the elevation elements of the structure. For the purposes of this study the student concentrated on developing the 3D model of the exterior of the structure. Certain components of the model were redesigned and the student spent considerable amount of time in achieving the desired exterior for the building. Figure 1 shows the original model of the building and the modified model re-designed for the study.

Figure 1: Original Model of Design (left) Modified model (Right)

For the generation of the 3D model in SketchUp the student first imported the CAD drawing of the building; after following scaling and exploding operations, drawing surfaces were created from the imported lines and pushed/pulled to generate the exterior façade. The student then measured areas from the CAD drawing to place windows and other components of the elevation. All windows, doors and elevation elements were designed and modeled specifically for this building, imported components were not used. Most of the materials used for the building elements were selected from within SketchUp itself with color and size being modified; a few of the materials were imported into the model. The model as a whole took about 70 hours to

generate over a period of 1 ½ months. The major elements modeled were the trusses that were designed for the portico and entrance areas. This was a design feature which the student felt would enhance the elevation of the structure. These were built as a component and needed to be modified each time the length changed. The trusses themselves took about 10-12 hours to build; this was apart from the time spent building the entire model. Figure 2 illustrates the completed SketchUP model.

Figure 2: Completed SketchUP Model

Upon completion of the model the student began the rendering process. Four ~~different~~ software programs were used to render the model. Two plug in software programs; V-Ray and Twilight, and two stand-alone programs; Kerkythea and 3DS Max were the chosen rendering platforms. An enhanced partial view of the building was rendered with V-Ray and Twilight and for the stand-alone programs, Kerkythea and 3DS Max a view of the entire front and side of the building was rendered. The stand-alone rendering programs were installed in the computer laboratories of the department and so the student decided to use them for the purpose of the study. V-Ray is a very popular rendering engine and used by professional firms while renderings completed using Twilight can be easily exported into Kerkythea for further enhancement if needed hence they were selected for the study. The student had previously experimented with Kerkythea but had not worked with the other three programs. Following the rendering, post-production work was done on one of the rendered images in Photoshop to add entourage and other features to make the image more realistic.

Outcomes

Table 1 shows the steps involved in creating the renderings for each of the four software programs. There is a certain commonality that exists in the setup for each of the selected programs. The rendering process begins with the selection of the view to be rendered. One of the important aspects for students to keep in mind is the purpose of the rendered image; to explain and illustrate the strongest architectural intentions [14] of their project. Two different views were

Setup				
	V-Ray	**Twilight**	**Kerkythea**	**3DS Max**
1	Selection of view in SketchUP	Selection of view in SketchUp	Export SketchUP file as XML	Import SketchUp file into 3DS Max
2	Select Location	Shadow Settings- Select month Time of day	Import the XML file into Kerkythea	In the 3D view select shaded view
3	Turn on Shadows in SketchUP	Twilight –Render Dialog Box	Change Wire Frame to Solid Rendering	Assign Materials- Extract embedded textures
4	Adjust environment settings in V-Ray	Select -height and width of rendered image -method of saving -Preset- Express-Easy - Exterior Daytime (08)	Adjust Sun and Sky	Un-group the building to be able to select only the material to work on. Using material editor modify materials- (9 steps)
5	Adjust Output in V-Ray	Render	Camera and settings -Select Resolution	Create Tab - Systems- Select Daylight System- Position compass
6	Render		Select -year and day -location -Sky type	Daylight modifier Sunlight- Mental Ray (MR) Sun-Check Active Skylight- MR Sun-Check Active
7			Start Render button	Select -Date -time and Location
8			Edit material and change transparency of windows	Sky Parameters Change sky model to haze driven and select ground color
9			Render	Render Setup- Assign Renderer- Mental Ray Pick Area to Render Rendering Resolution
10				Render

Table 1: Setup Process of Rendering Software

rendered in this study; the first highlighting the portion of the building which would show the truss, an important architectural element and the second an entire façade view to provide an overall feel of the architectural style of the building. Other steps that are common in the setup include selection of the location of the project and month and time of day for the rendering scene. Typically location of the project is the physical location of the project, an option that exists in all four software programs used for this study. The month and time of day selection depends on the required extent of shadow generation, or if a day or night rendering is desired. Choosing the required resolution of the rendering is also an important aspect to achieve the desired rendering quality.

In observing the steps involved in each of the programs, it was noticed that the plugins had fewer steps required than the stand-alone programs. To get basic renderings the student downloaded the plug- in into the program and adjusted the shadow settings, selected the month and time of day, then selected the render dialog box and selected the appropriate resolution and began the rendering. Steps were relatively simple for the plug-ins.

Table 2 highlights the time taken for setup and rendering for each of the programs. In the case of the plug-ins the setup took a maximum of 10 minutes for each of the programs, and, while there are many more complicated steps that could be added on, these basic steps will enable students to get a rendering of acceptable quality for presentations. The V-Ray rendering took about 35 minutes but the Twilight rendering took more than 40 hours to complete, this was due to the 'Exterior Daytime' preset selected. Quicker renderings can be achieved using the low or the medium preset, but the quality of the completed rendering was not as desired. In both the plug-in programs SketchUP materials were used and materials were not modified, this made the setup quick and easy. Final rendering for V-Ray and Twilight can be seen in Figures 4 & 5.

Time Utilization		
	Setup Time (hours, minutes, seconds)	Rendering Time (hours, minutes, seconds)
V-Ray	0, 10, 0	0, 35, 0
Twilight	0, 10, 0	40, 30, 31
Kerkythea	0, 20, 0	0, 05 ,0
3DS Max	2, 00, 0	0, 40, 0

Table 2: Time Utilization

Figure 3: Base SketchUP model view used in the V-Ray and Twilight Rendering

Figure 4: Rendered Image using V-Ray

Figure 5: Rendered Image using Twilight

As observed in table 1 for rendering in Kerkythea the first step had to be worked in SketchUP. SketchUP extensions cannot be imported into Kerkythea hence the file was exported as an XML file and then opened in the rendering program. For the rendering in Kerkythea, materials that were imported from SketchUp were used which reduced the number of steps required. After the rendering was completed the window opacity was changed as the windows did not look as desired and the scene was re-rendered. The 3DS Max setup was the most complicated as the student experimented with materials from 3DS Max, which added a slew of steps to incorporate materials from within the 3DS Max material library. Table 1 indicates a total of 10 steps for the 3DS Max rendering and while these are the major steps required, the process for assigning materials itself consisted of 10 steps that involved extracting materials used in SketchUP, ungrouping and selecting the areas of the view where materials needed to be added, selecting color in the material map browser, adding material to the selection and changing glossiness depending on material being used and adding texture to the color.

The setup time took longer for the stand alone programs as shown in Table 2 which is evident considering the increased number of steps. The setup for 3DS Max took the longest about 2 hours due to assigning of materials. The rendering time was very quick in Kerkythea; 5 minutes and the 3DS Max rendering took 40 minutes. Final rendering for Kerkythea and 3DS Max can be seen in Figures 7 & 8.

Figure 6: Base SketchUP model view used for rendering in Kerkythea and 3DS Max

Figure 7: Rendered view in Kerkythea

Figure 8: Rendered image using 3DS Max

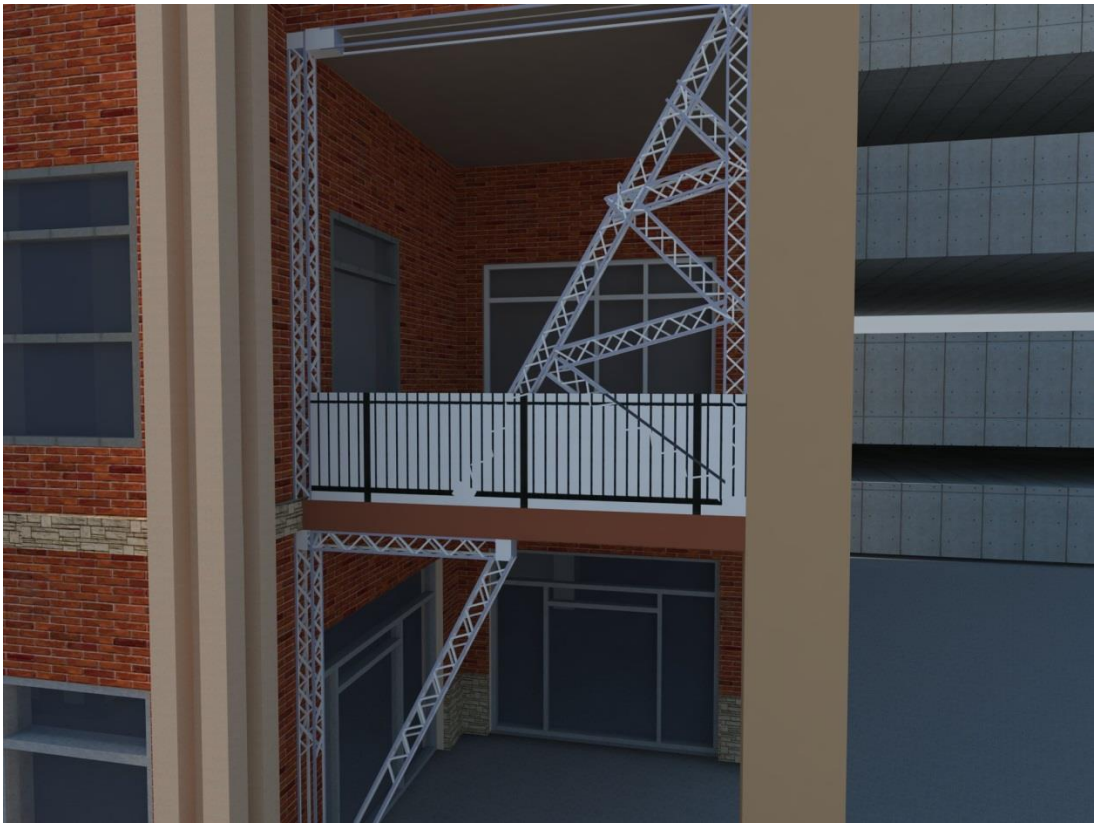

Figure 9: Image showing failure of railing to render

The study required the student to experiment with all the four software programs. The student spent a considerable amount of time viewing videos and tutorials over the internet. The student also reviewed manuals for each of the software programs. One of the difficulties encountered during rendering was trying to achieve the right appearance of the railing on the balconies and terrace. When the student rendered the model with the railing in place the railing did not render appropriately as seen in figure 9. Hence for subsequent renderings the railing was removed and re- added to the image in post-production work. Trivial problems were also encountered for which the solutions while simple were not immediately obvious, for example, when trying to open the XML file in Kerkythea, initially the student could only view the windows and no other part of the model. The problem was resolved after switching machines. A considerable amount of time was spent on familiarization with 3DS Max for assigning materials.

This discussion would not be complete without defining criteria that would determine the success of a rendering. A successful rendering should be able (1) to convey the design intent, (2) highlight important architectural elements, (3) reflect realism in material color and texture, and (4) portray light and shadows adequately. Design intent is a concept that is best defined by the design team; we hence use criteria 2, 3 and 4 to analyze the rendered images. Renderings in V-Ray (figure 4) and Twilight (figure 5) show a view of the building highlighting the trusses which form one of the key architectural elements of the structure. Renderings in kerkythea (figure 7) and 3DS Max (figure 8) show an entire façade view which gives the viewer the overall picture of the building. It can be noticed that the color of the brick rendered in Twilight and Kerkythea has an orange hue while the V-Ray and 3DS Max rendering of the brick is more realistic showing the brick having a brown hue. Additionally the truss rendering in V-Ray and 3DS Max has been depicted as a truer metallic color while in Twilight and Kerkythea they appear white. The glass pane is more transparent in V-Ray when compared to Twilight and kerkythea, whereas in 3DS Max the glass panes were too transparent in certain areas. Similarly the light poles are lit in V-Ray and 3DS Max while this is not the case in Twilight and Kerkythea. Light and shadows in the rendering depend on month and time of day. All the renderings were done for the month of May, using natural daylight and show appropriate light and shadows.

Another useful parameter for measuring the effectiveness of a rendering tool is the ease of setup and complexity of pre-rendering steps and the time taken for computing, here we take a look at the number of unique steps required to setup a rendering scenario and specifically if these steps require a more in-depth knowledge of what the rendering entails. For example, time of day for a given rendering is a relatively easy setup parameter to understand on the other hand assigning materials such as that done in 3DS Max is a more complex concept requiring much more time, understanding, judgment and effort to implement. Finally the time taken for computing, to obtain the final rendered image is a very important criterion to be mindful of when planning a rendering. For students the insights gained with a rendered image which achieves a given effect say in 1 hour is more than that of a rendered image that takes more than 24 hours to achieve a subtly more enhanced rendering. On the other hand entirely different considerations may be in effect for a professional rendering.

Conclusion

The rendering process is different from other digital visualization techniques and tools in that the core rendering process is not interactive. Once the rendering is setup and initiated the user does not have control over the process till the rendering is completed. This may take anywhere from a

few minutes to several hours. For this reason, ideally a rendering should be setup with an expectation of the results. This would obviously require a significant amount of trial and error initially with various settings and parameters which are specific to the rendering software in use and would ultimately provide the required experience to enable the student to have a reasonable expectation of an outcome of the rendering for a given group of settings. With the settings that were used, the final images rendered at different grades of appearance and different rendering times. It is possible that varying these settings may yield a significantly different outcome for the same renderers. Experience would be the most practical indicator of what these settings should ideally be.

Professional renderings can take hours to setup and render and in most cases a lot of time is spent in post-production work adding details and entourage. The renderings produced during this study's reflect basic renderings that can be achieved with minimum setup steps and as little time as possible for actual rendering; reaching a standard that is acceptable for a student. Doing these basic renderings successfully will give students the impetus to constantly keep improving and trying new techniques, ultimately achieving more professional work.

There is little doubt that rendering is a discipline in itself that needs investments of time, money and training in order to gain proficiency and realize returns. Rendering is unique in that its technical aspects demand a significant level of training but its application and utility is as much for end visualization by clients and professionals as it is for marketing a project. It needs to be emphasized that the current trend has made the rendered model one of the primary assets in the arsenal of the designer which could make a difference between winning and losing a commission. In the AS program in the AMS department the focus is heavily oriented to training students to be highly proficient in the areas of design and creation of construction documents. It is logical to appropriately enhance syllabi to incorporate the right amount of training and practical exposure of students to rendering concepts and tools so that they are prepared to use it effectively for design expression to a potential client.

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