

Teaching Using 3D Laser Scans

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This paper discusses the feasibility of using three dimensional (3D) point scans in teaching construction management (CM) courses. The differences in teaching and learning styles result in problems such as disengagement of students, and lack of understanding of the subject matter. Studies have shown that the most of the CM students are visual learners. A visual learning environment which enhances students learning capabilities is required to engage the students. The point clouds generated through laser scanning create data rich 3D visual models and provide opportunities to address the challenges faced by the students during the visualization process. 3D laser scanning is a very effective and efficient approach for precise and dimensionally accurate 3D as-built documentation. 3D laser scanning is a process of collecting the spatial coordinates of points of an object by using lasers. The point clouds generated in this process are useful for measurement and visualization applications and serves as an excellent tool for teaching courses. This paper discusses the different approaches of data collection for producing 3D scans useful for teaching CM courses.

Key Words: 3D, laser scan, learning environment, visualization

Introduction

Students have different learning styles. Based on learning styles students can be categorized as visual and verbal learners. Visual learners learn through visual representations such as pictures, figures, sketches, and films whereas verbal learners learn through written or spoken explanations (Felder and Soloman, n.d.). Teaching means also vary. Traditional lecture format is one of the styles which is widely used for teaching construction management (CM) courses. Additionally, two-dimensional (2D) drawings are most widely used as pedagogical tools for teaching CM courses to the students. The interpretation of 2D drawings by students varies based on their educational background, previous practical experience, and visualization capabilities (Wasim et al., 2011; Irizarry and Meadati, 2009). Students are required to develop three-dimensional (3D) models mentally by visualizing the different components of the project. Students with little or no practical experience often face challenges and spend more time in developing 3D visual models. Sometimes, the lecture format style is complemented by including construction site visits. This teaching style provides visual and verbal learning environment. However, inclusion of site visits within the course schedule is not always feasible due to reasons such as unavailability of construction sites meeting the class needs, class schedule conflicts, and safety issues (Haque et al., 2007). Due to the lack of adequate visual learning environment, currently CM students are unable to gain the required skills to solve real world problems (Abulrub et al., 2011; Wasim et al., 2011; Irizarry and Meadati, 2009). The differences in teaching and learning styles result in problems such as disengagement of students, and lack of understanding of the subject matter (Felder and Silverman, 1988). To assess the learning style of the students a survey was conducted at Construction Management Department, Southern Polytechnic State University. Index of learning styles questionnaire proposed by Soloman and Felder of North Carolina State University (Soloman and Felder, n.d.) was used to assess the learning styles. It is an on-line instrument questionnaire and has 44 questions. Once the survey is submitted the learning styles of the student are presented on scale score ranging from 1 to 11 in increments of 2 for each learning style. Depending on the score, the students preference to particular learning style can be classified as “fairly well balanced” (score on scale 1-3), “moderate” (score on scale 5-7), and “very strong” (score on scale 9-11) (Soloman and Felder, n.d.). Fairly well balanced indicate that the student is flexible in adopting either learning style. Moderate indicates student’s moderate preference to particular learning style. Very strong indicates student’s strong preference to the particular style. For this study, visual and verbal categories were only considered. Each student of the course was asked to complete the survey. The results of the survey were then analyzed to assess the different learning styles of the students enrolled for the course. Total 16 students were enrolled for the course. But only 12 students took this survey. The survey results of the 12 students are shown in Table 1. Based on survey results, 83.33% and 16.67% were categorized as visual and verbal learners respectively. As shown in Figure 1, based on the scores 20%, 20% and 60% were considered as fairly well balanced, moderate and very strong visual learners respectively. Under verbal learners category 100% were considered as fairly well balanced learners. As fairly well balanced learners are able to adopt any learning style, all the students were categorized as visual learners for the further study. Considering the students learning style the authors created a visual learning environment which helps them to match the students learning styles and enhance their learning capabilities. 3D laser scanning is a very effective and efficient approach for precise and dimensionally accurate 3D as-built documentation. The point clouds produced through 3D laser scanning techniques creates rich visual learning environment. The point clouds generated are useful for measurement and visualization applications and serves as an excellent tool for teaching courses. This paper presents the applications of the 3D point clouds in the construction education. The study was conducted at Construction Management Department, Southern Polytechnic State University.

Table 1: Scores for Visual and Verbal Learning Style Categories

Student #	***Visual***	***Verbal***
1		1
2	9	
3	7	
4	7	
5	3	
6	3	
7	5	
8	9	
9	5	
10		3
11	7	
12	7	

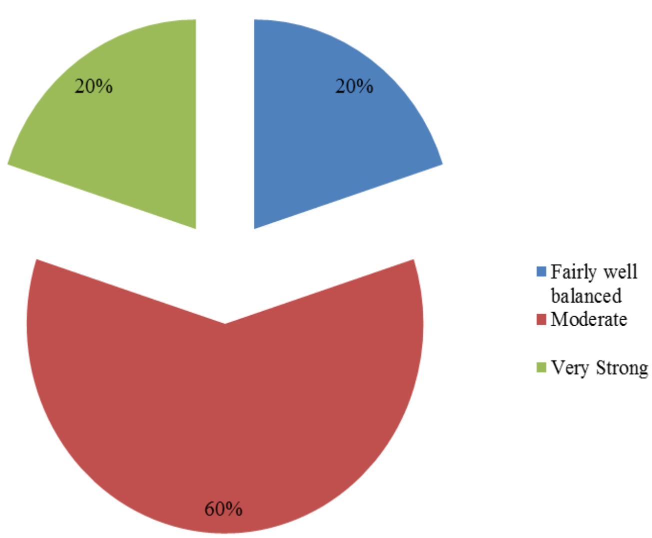

Figure 1: Visual Learners and their preferences

3D Laser Scanning

3D laser scanning is a very effective and efficient approach for precise and dimensionally accurate 3D as-built documentation. 3D laser scanning is a process of collecting the spatial coordinates of points of an object by using lasers. The point clouds generated in this process are useful for measurement and visualization applications. This approach reduces errors and rework during documentation and enhances the productivity in a construction process. 3D laser scanning technique has been successfully used for various architecture, engineering and construction applications (Shin and Wang 2004; Olsen et al. 2010; Jaselskis 2005). Walters et al. (2008) used laser scanners to determine the thickness of concrete pavement. Tsakiri et al. (2006) calculated the deformations through usage of surface reconstruction and deformation extraction techniques from laser scanner data. Gordon and Lichti (2007) used laser scanner data for modeling to calculate the precise structural deformation. Chang et al. (2008) used 3D laser scanner data for deformation calculations for evaluating the structural safety. The Objective Driven Data Acquisition Approach (ODDAA) and the Fully Automated Data Acquisition Approach (FADAA) were the two techniques used to collect the data for the development of 3D as-built model. The ODDAA is also referred as “sparse range point cloud” approach (Kim et al. 2005). Only target points are scanned in ODDAA. This approach includes human involvement for targeting the objects and makes it semi-automatic instead of fully automated data acquisition used in the FADAA. An individual target object is selected and x, y, and z coordinates of a minimum number of points is acquired to represent the object in a 3D model. The 3D as-built model is developed by selecting the target object from parametrically defined graphical objects stored in the database and placing it spatially using the scanned x, y and z coordinates. The density of the data used for modeling is substantially less when compared to the FADAA. The x, y, and z coordinates of the as-built components can be acquired by using a total station (see Figure 2a). These coordinates are used for developing the 3D as-built guide line layout. This guideline layout is further used for developing 3D as-built model (Goedert and Meadati, 2008). In the FADAA, 3D laser scanner (see Figure 2b) is used to produce a dense point cloud. These scanners converts captured xyz coordinates of millions of points all over an object to recreate a digital image. 3D scanner converts physical objects into digital 3D data. The required data collection is achieved by scanning and merging the dense point clouds collected from various locations. Then this data is used for developing a 3D model. This approach provides a very accurate and detailed 3D model (Kwon et al. 2004).

Figure 2a: Total Station

Figure 2b: 3D Laser Scanner

Teaching Using 3D Scans

3D scans facilitate the usage of 3D models in teaching courses and provide opportunities to address the challenges faced by the students during the visualization process. The 3D scan characteristics such as easy visualization and simulation capabilities allow visual and kinesthetic learning environments. These environments allow students to discover strengths and weaknesses of their learning practices and facilitate self-improvement. As shown in Figure 3, 3D scans have the potential to greatly enhance the educational experience of CM students in acquiring skills related to different areas and will provide faculty with a tool that can improve teaching different courses in a more visual and interactive way. The following sections present an overview of how 3D scans were used in teaching some of the courses at Construction Management Department, Southern Polytechnic State University.

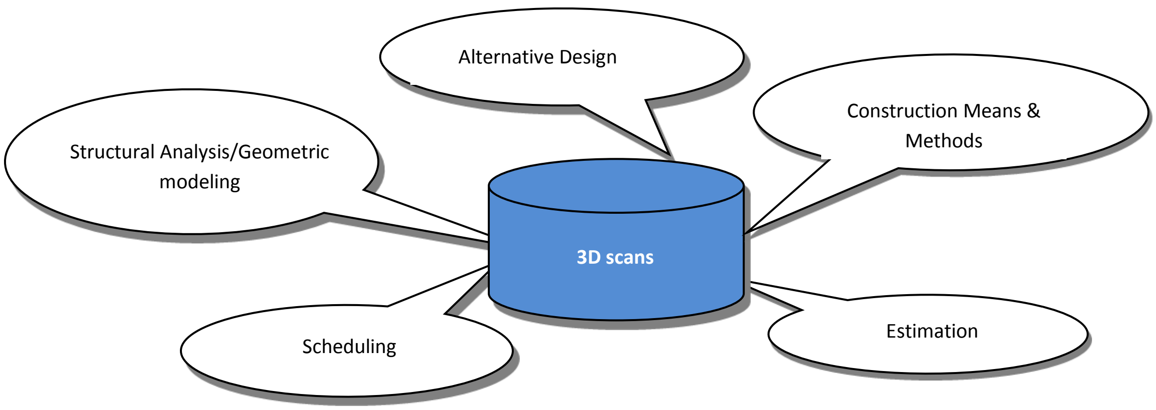

Figure 3: Applications of 3D scans in teaching CEM courses

Structural Analysis/Geometric Modeling

In order to explain the mechanical behavior of the rubble walls of the rubble house built at Southern Polytechnic State University, a displacement response map of the walls was recorded using a 3D laser scanning technique. In this project, FARO laser scanner Photon 20/120 was used for documenting the wall displacements for out-of-plane loads and a destructive test. It is a high accuracy, high resolution scanner. It scans at the rate of 976,000 points per second with a reach of 503 ft. This means it produces an image by collecting 976,000 points 3D ordinates per second within 503 ft distance. It has range resolution of 0.07 mm for 503 ft (153 m). Range resolution can be defined as smallest part of a signal that can be observed (Mackinnon et al., 2009). It has systematical distance error of ±2mm at 25 m. It has 320^{o} and 360^{o} field of view in vertical and horizontal directions, respectively (FARO, 2010). A 3D scanning for the house was performed after each loading step at three different locations. A scan file of 90MB size was generated within 6 minutes. A total of 5 spheres have been used during the scanning process. These spheres were used for registering different scans during post data processing. FARO SCENE LT software is used for processing the scanned data. In order to determine the displacement response of each wall, a number of points on the wall were selected on the West Wall (see Figure 4a and Figure 4b).

Figure 4a: Out-of-plane loading on west wall

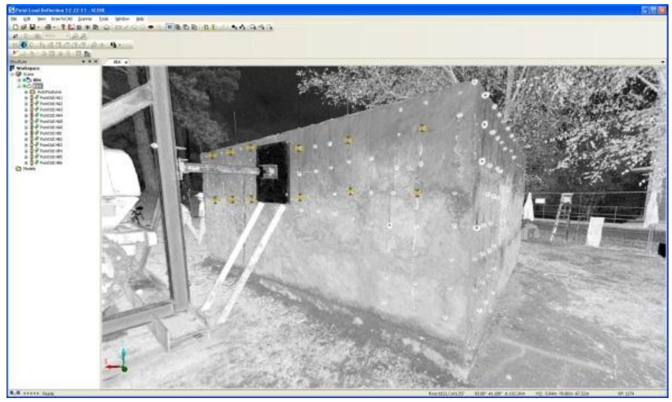

Figure 4b: 3D scan view of west wall during Out-of-plane loading

Estimation and Alternative analysis

The Engineering and Technology Center building at Southern Polytechnic State University (see Figure 5) was considered to study the alternative analysis for one of the exterior walls. FARO Focus 3D laser scanner was used for scanning the building. This is small and lightweight scanner. It is a high accuracy, high resolution scanner. It scans at the rate of 976,000 points per second. It has range resolution of 0.07 mm. It has systematical distance error of ±2mm at 25 m. It has 305^{o} and 360^{o} field of view in vertical and horizontal directions, respectively (FARO, 2011). The scans were processed in Revit Architecture 2012 to produce a 3D model. Then this model was used to evaluate exterior wall finish options. The options considered include brick or stucco finish. In the course, the students were given this model and were asked to prepare the cost estimates for these options. Students accomplished the cost estimates by using "Schedules/Quantities" feature in Revit. Using this feature the material quantities were extracted and these were used to prepare the cost estimates for these options.

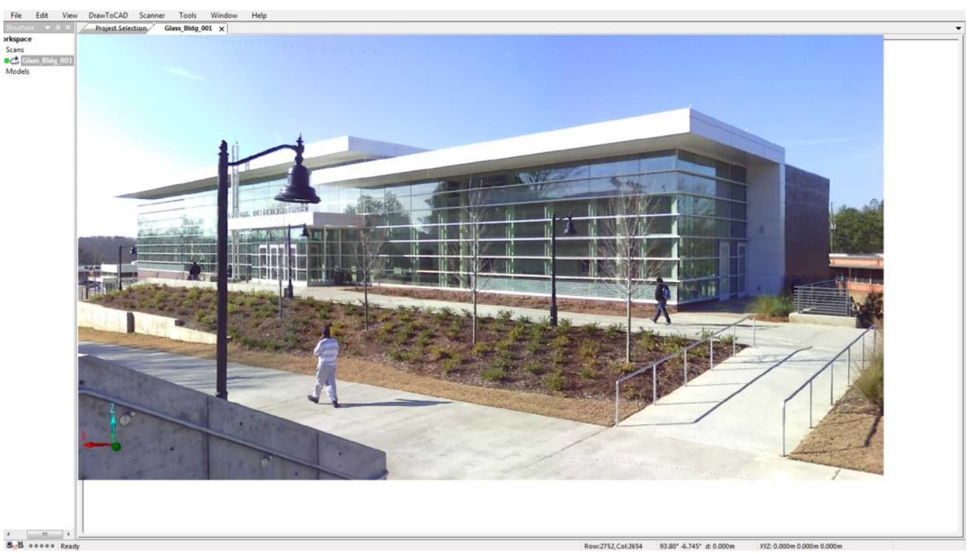

Figure 5: 3D scan of Engineering and Technology Center

Constructability Analysis

Traditionally, the construction sequence is taught by using 2D drawings and critical path method (CPM) bar charts. Students need to develop 3D models about the construction sequence in their minds to correlate the relationships between different components of the project and schedule activities. Lack of 3D model visualization skills limits the students' ability to comprehend the construction sequence (Messner et al. 2003). The short comings of these traditional methods can be addressed by using four dimensional (4D) modeling (Koo & Fisher, 2000; Kang et al. 2004). Plumbing and HVAC system of a building at Southern Polytechnic State University (see Figure 6) was scanned and used for teaching one of the courses at Construction Management Department of Southern Polytechnic State University. In this course students were asked to develop a construction schedule using 2D drawings produced from the scanned models. Then the developed students' schedule was simulated to them visually through 4D modeling. The 4D modeling was accomplished through Autodesk's Naviswork Manage software. The 4D model was generated by developing 3D model in Revit MEP through scanned models and integrating it with the students' schedule. These simulations helped to explain and communicate the construction process to the students better than 2D drawings and CPM bar charts.

Figure 6: Plumbing and HVAC system of H building

Conclusion

3D laser scanning provides an opportunity to collect dense point cloud. The point clouds generated in this process are useful for measurement and visualization applications. These can serve as an effective tool to enhance the visualization capabilities of the students. The 3D scan characteristics such as easy visualization and simulation capabilities allow visual and kinesthetic learning environments. These environments allow students to discover strengths and weaknesses of their learning practices and facilitate self-improvement. 3D laser scanning technique has been successfully used for various fields. However these scanners are not used widely because of high cost and more computing hardware requirements for post processing the data. The continuous evolution of technology and computing hardware will make these scanners affordable. 3D scans has the potential to greatly enhance the educational experience of CM students in acquiring skills related to different areas and will provide faculty with a tool that can improve teaching different courses in a more visual and interactive way.

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