Effective Use of a Digital Demonstrator for the Instruction of Laser Scanning

Steven Kangisser, and Abhishek Shankar, and Javier Irizarry Ph.D.
Georgia Institute of Technology,
Atlanta, Georgia

This research contributes to the understanding of digital demonstrators as a tool for classroom instruction in the use of laser scanners. Laser scanning technology plays an essential role in construction management. At the university level, students in this domain must demonstrate theoretical knowledge through hands-on exposure to laser scanning technology. Obtaining laser scanners requires a substantial capital investment as well as ongoing maintenance costs. This impedes the ability of many institutions to provide scanners for classroom use, resulting in a scarcity of such equipment and posing an instructional challenge. Use of digital demonstrators offers the potential to augment or replace a physical laser scanner in the classroom. For this study, researchers examined the current method of scanner instruction and developed a simulated scanner which functions as a digital demonstrator. The use of the demonstrator was subjected to mixed methods analysis using both undergraduate and graduate student subjects at the Georgia Institute of Technology. Testing concluded that integrating the digital demonstrator in the instruction workflow enhanced student learning and enabled those who used it to rapidly adapt to a physical scanner. The paper finally offers suggestions for further research including wider testing and examination of broader applications within STEM instruction.

Key Words: Digital demonstrator, Laser scanning, Construction education.

Introduction

Laser Scanners are widely used in the construction industry to capture details of existing structures and objects. Laser scanners analyze the built environment, including real-world objects, by collecting data on shape and appearance. The resulting data is frequently applied to develop digital three-dimensional models. (Ebrahim, 2015). Laser scanners use laser beams to create a three-dimensional point cloud. The scanner sends out a laser beam and calculates resulting point cloud information based on the amount of time taken by the beam to return to the scanner. These point clouds can then be used to derive accurate information about the mapped area's dimensions.

Instruction of laser scanning skills requires students to apply theoretical knowledge through hands-on exposure to laser scanner technology. This instruction must often be accomplished with the availability of few or no physical scanners. The limited availability of scanning instruments presents a challenge when class sizes are large, as the instrument-to-student ratio does not permit each student reasonable hands-on access. Also, when such courses are offered remotely, access to the equipment required to gain this exposure can impede the accomplishment of the stated course objective. At the Georgia Institute of Technology School of Building Construction Management, laser scanning is taught to students both at the undergraduate and graduate levels. A typical semester combined cohort size is approximately sixty-five students, yet the School posses only two instructional scanners.

The development of a digital demonstrator which could augment or replace a physical laser scanner was developed as a solution to the limited or non-availability of physical scanners. To accomplish this task, the researchers examined the current method of scanner instruction at the undergraduate and master's degree levels. A simulated scanner was then developed and tested by an initial introduction to a test group of high school students, followed by a graduate and an undergraduate class at the Georgia Institute of Technology. Student performance was measured using a mixed methods approach. The results of these tests are detailed in this article, along with conclusions concerning the effectiveness of a digital demonstrator for the instruction of laser scanning.

Background

Learning through a digital demonstrator is, in many ways, like simulation gaming. In gaming, the goal is to simulate a decision-making process and demonstrate the consequences of incorrect decisions. Kriz (2003) defines games as "the simulation of effects of decisions made by actors assuming roles that are interrelated with a system of rules and with explicit references to resources that realistically symbolize the existing infrastructure and available resources." There are two types of simulation games, open and closed. Open games lack a clearly defined ending and permit players to establish goals based on personal preference. The digital demonstrator is more similar to closed games as rigid rule simulation is incorporated. Players receive clear instructions which are based on well-defined rules. The problem statement is presented to the player within a well-defined framework. Participants must solve the problem precisely while adhering to the rules. The simulation model, rules, and flow are not stated explicitly in open, free-form games. Hence, a reflection phase is needed when teaching specific skills through gaming simulation. During reflection, participants can apply the knowledge acquired during the gaming simulation to the real world.

Digital demonstrators are also similar to flight simulators. Tiffen and McCormik (1986) discuss how learning with flight simulators require that students have the aptitude, ability, motivation, and opportunity to practice what they have been taught. They explain that the ability to put what has been learned into practice allows students to determine if they have achieved the level of knowledge necessary to make correct decisions. The authors describe that flight simulators must be designed to include specific learning goals required to perform a task. Flight simulators are also used as a testbed before actual flight validation. Ratvasky and Barnhart (2007) discuss how a concept demonstrator was used to understand deicing effects in an airplane to validate flight data results. By training with a digital demonstrator, pilots could understand how an aircraft handled in different icing conditions before they were at the helm of the aircraft. They could then provide verbal comments comparing their experiences in the simulator to those in-flight, and the data would be used to validate the pilot's flying decisions.

Training exercises have been demonstrated to be critical to gaining competence as part of knowledge transfer for complex skills. Advanced computing has recently enabled the integration of more serious games and simulations in skill training. The use of these tools has increased dramatically for training that is complex, time-critical and involves high risk. Simulators can now provide the learner with visualizations of the environment and the dynamics related to the user's actions (Aronsson, Artman, et all, 2021).

The availability of an open platform digital tool specific to laser scanning can be highly beneficial for construction faculty charged with introducing laser scanning in their courses. While digital demonstrators and simulators as teaching tools are not new, educators must expend valuable teaching/research time constructing such tools appropriate for the learning goals of their specific course (Wolffe, 2002). The digital demonstrator considered in this research is designed to address this issue for the instruction of laser scanning within construction courses at the university level.

Methodology

The work plan for this research is illustrated in Figure 1. It encompasses nine primary activities, including a literature review, identification of stakeholders, developing a digital prototype, conducting a cognitive walkthrough, a pilot test, prototype refinement, introduction to a graduate-level class, introduction to an undergraduate-level class, and the evaluation of test results.

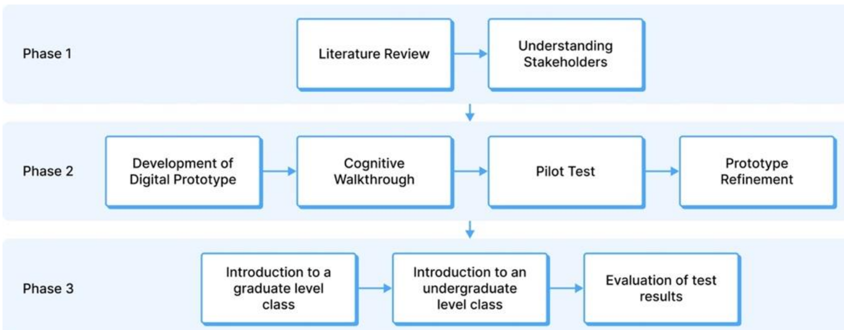


Figure. 1 Methodology

Understanding the Stakeholders

The initial task for this study was to understand the needs of the stakeholders who interact with laser scanners in the classroom. To accomplish this task, researchers observed instructors' and students' interaction using a physical scanner in a traditional classroom setting. Observation included a graduate course in Construction Tech, offered most semesters in the School of Building Construction Management at the Georgia Institute of Technology. Such traditional scanner instruction is performed using limited instruments compared to class size. It was determined that there are two stakeholders, instructors, and students. For instructors, it was observed to be desirable to develop a demonstrator with which the instructor can teach students the setup and operation of a laser scanner. Instructors should be able to use the tool to test students' knowledge of a scanner's operation for both formative and summative evaluations. Instructors should also have tools to measure proficiency in scanner operation. Students be able to access the laser scanner demonstrator both synchronously and asynchronously, as not all learning occurs during scheduled class time.

Development of a Digital Prototype

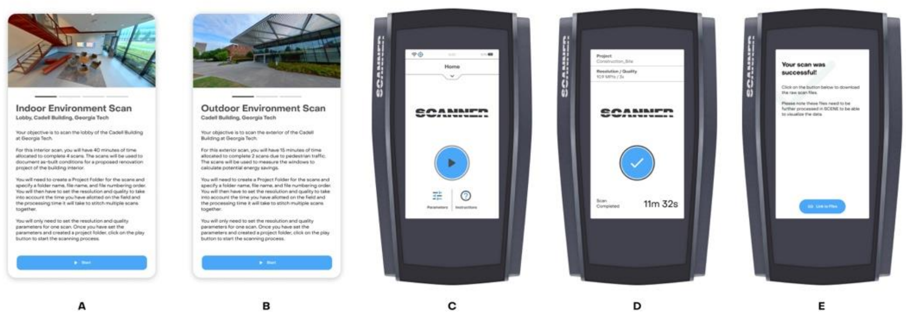
The results of the first phase, user analysis, informed the design decisions made in the design phase. Understanding the needs of both instructors and students, the researchers determined that designing multiple distinct operational modes would permit greater flexibility for all users. For this reason, an access mode and an assessment mode were developed. To reflect a variety of commercially available laser scanners, the design decision was made to develop a generic scanner inspired by available models but responsive to the needs of new users. The design phase was carried out in Figma, a tool that allows the development of wireframes. Wireframes were then carried over to Protopie, a high-fidelity prototyping tool commonly used in user interface design. High-fidelity interactions were designed using this Protopie software. The digital demonstrator is viewed on a browser window hosted on the Protopie cloud.

Figures 2A-F. Access mode screens

The first use mode of the demonstrator is the access mode. The access mode is an unrestricted mode aimed at instructional and practice usage. This mode has full access to the digital demonstrator and has no constraints on the device settings. All of the laser scanner settings can be modified by the users. Instructors can employ the access mode as a teaching tool during class instruction. Students can follow along during a lecture interacting with the laser scanner as they see beneficial. The access mode is depicted in Figure 2. Using the access mode, students can follow up after a lecture, further familiarizing themselves with the laser scanner at their own pace. The use of the access mode begins with the home screen.

The home screen (Figure 2A) is the main landing screen for the prototype and houses all the critical interactions of the laser scanner simulator. While on the home screen, users can access the scan button, represented by a blue play circle. Clicking on this button initiates the scan. The parameters button on the left lets the user choose from different settings required for a given scan scenario. These settings include resolution and quality, a user profile, the scan area, and the color mode. The view scan button lets the user preview the scans the scanner has taken. The user can select and view the information about the settings of the scans taken. The manage button allows the user to explore the settings of the scanner's user interface. Users can also add projects under which their scans will be housed, see operators' details for the device and explore the different preset scanning profiles. The help button in the top right corner of the home screen redirects users to this documentation if the users have any questions about the operation of the laser scanner simulator.

The next screen (Figure 2B) allows the setting of all scan parameters. This screen includes profile, resolution, quality, scan area, sensors that can be toggled on or off, and the option to scan in color. The screen illustrated in Figure 2C includes all resolution and quality selections. Students frequently find it challenging to visualize the relationship between resolution and quality. To help students with this visualization, a visualization feature has been added to the demonstrator. Students then progress to the next screen, which allows users to set administrative functions for the scanner (Figure 2D). This includes customization with the project (Figure 2E) and operator names. The profile button lets the user view several presets for scanning built into the laser scanner. The general settings allow the user to explore the settings of the scanner's user interface, including the date and time, screensaver, and language options. The final screen presents the scan progress (Figure 2F), indicating the status of the scan in progress to the user.



Figures 3A-E. Assessment mode screens

Supplementing the Access mode is the Assessment mode. The assessment mode is a restricted functionality mode aimed at enabling instructors to assess student proficiency in the operation of the laser scanner device. This mode can be used for evaluation at both the formative and summative stages of assessments. While in this mode, the user has a randomly assigned scenario that they must navigate (Figure 3A, Figure 3B). Access to settings not pertaining to these scenarios is restricted in this mode (Figure 3C). The assessment mode permits instructors to gauge students' proficiency using the laser scanner in one of the two randomly assigned senarios. Students can use this mode to measure their proficiency and ability to operate a laser scanner. When the student demonstrates operational proficiency in the digital demonstrator, they are rewarded with a data set identical to what a physical laser scanner device would provide at the successful completion of a laser scan activity. Students can then use this data set to advance to the data processing and analysis stages outside this demonstrator's scope (Figure 3D, Figure 3E).

Cognitive Walkthrough, Pilot Test, and Refinement

To identify design shortcomings, the researchers first conducted a cognitive walkthrough. Described by Lewis, Polson, Wharton, and Rieman in 1990, a cognitive walkthrough is a usability inspection method designed to bring together an interface evaluation and a cognitive model (Mahatody, 2010). Researchers presented the digital demonstrator interface to a graduate student with limited exposure to scanner use. The student was asked to perform a laser scanning task using the demonstrator tool. The student verbalized his actions and described why each action was selected. The research focus was on the cognitive activities of the student, including their goals and knowledge when performing each task. Errors were observed and recorded with particular attention to the cause of each error and the student's description of what they were looking for at the moment. Based on this analysis, several refinements were made to the digital demonstrator.

Following the cognitive walkthrough, the digital demonstrator was used to instruct a cohort of high school students on the use of a laser scanner. These students were selected as they allowed the researchers to access test subjects who were available at that time at the Georgia Institute of Technology building construction summer camp without exhausting the limited number of university-level construction students who could later participate in a more directed analysis of the tool. Clicks on the web-hosted prototype were monitored using Useberry, an online codeless prototype analytics platform based in Athens, Greece. Time on task and errors were recorded. Figure 4 illustrates the results of this pilot study. In general, the high school students found the prototype easy to moderately easy to use. Lack of motivation from students performing the learning task in the absence of course objectives or student grading was a limitation. Still, refinements were indicated, and the digital demonstrator was modified to reduce confusion and permit additional actions.

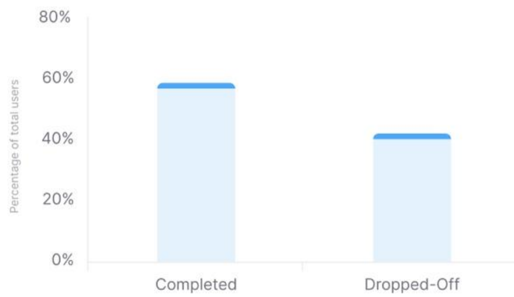


Figure 4. Pilot test completion rate

Implementation with Graduate and Undergraduate Students

Having conducted initial testing and refinement of the digital demonstrator, the resulting prototype was employed to instruct students in the use of laser scanning within courses at the Georgia Institute of Technology. The demonstrator was integrated into an undergraduate and graduate-level course during the fall 2022 semester. In both cases, the courses were on technology applications in building construction. During prior semesters, instruction in laser scanning relied on the use of FARO Focus laser scanners. The School of Building Construction Management owns two of these scanners. Students were first instructed using a PowerPoint presentation. After this, students gathered around a scanner provided in the classroom. Here they gained practical exposure to the setup of the physical scanner. Due to the availability of only two scanners, there are typically eight to fourteen students per scanner. Under these conditions, only a few students gain hands-on experience during instruction. With the digital demonstrator available, the instructor projected the digital demonstrator on a large screen in front of the class. Students used the online prototype of the scanner to accomplish tasks as discussed. Students then used the assessment mode to test their proficiency with the setup of a laser scanner. Each student's use of the access mode was tracked using the Useberry platform. Due to a technical issue with the interaction tracking platform, the researchers monitored only the graduate students while using the assessment mode. Some undergraduate students were not provided with the assessment mode. All the graduate students interacted with both the access and assessment modes.

Once the students completed using the digital demonstrator, they progressed to setting up a physical FARO laser scanner. They worked in teams of four to six students for this task. The teams then employed the FARO scanner to collect scanning data of an assigned area of the Cadell Building on the Georgia Institute of Technology campus. Once the data was collected, the graduate students were asked to provide verbal team feedback on using the digital demonstrator. Undergraduate students' feedback on the digital demonstrator was solicited using a written survey rather than verbal. Since not all the undergraduate students had been given hands-on access to the demonstrator, those who did not became the control group and formed a separate team for the purpose of data collection. The time required to set up the FARO scanner was monitored for each team, including the control group. After data collection, students worked individually to evaluate the scanning data, producing a model of their assigned portion of this building. Students were graded separately on data collection and processing, as well as project planning.

Results

Using the digital demonstrator with undergraduate students was shown to provide effective skill training. The students were able to interact with the digital scanner successfully. Those students who used the full digital demonstrator exhibited a far better understanding of the setup of the physical scanner based on observation. Figure 5 illustrates the time required to set up the Faro laser scanner. Teams one and two used the full digital demonstrator, while members of team three had not. Team three was less clear on how to set up a scanner and appeared to fumble along, making several corrections as they progressed. Teams one and two set up the physical scanner quickly and without error. The undergraduate students reported finding the digital demonstrator extremely easy to use and prepared them to interact with a physical scanner (Figure 6). Students reported that the demonstrator was a beneficial tool for learning laser scanner skills.

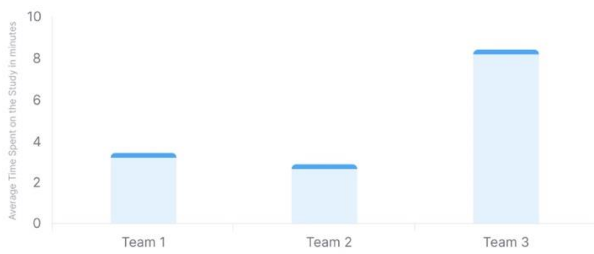


Figure 5. FARO scanner setup time

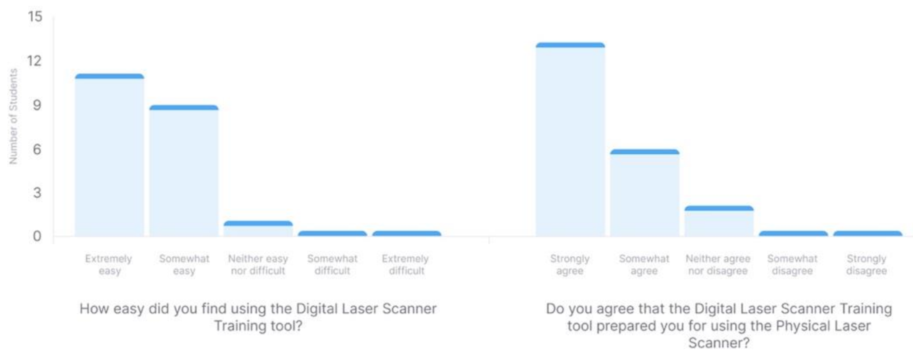


Figure 6. Student opinion on the digital demonstrator

Similarly, the graduate students found the scanner easy to interact with. Figure 7 illustrates the normal distribution of students' time on task when using the digital demonstrator. The graduate student's verbal evaluation of the digital demonstrator as a tool for learning how to set up a physical scanner is illustrated in Figure 8.

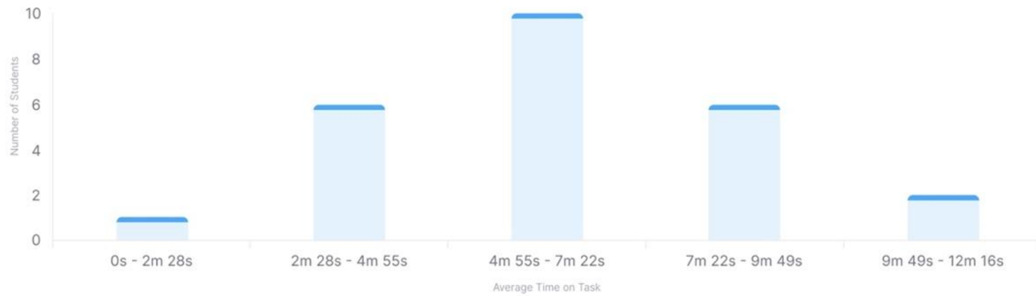


Figure 7. Time on task, assessment mode

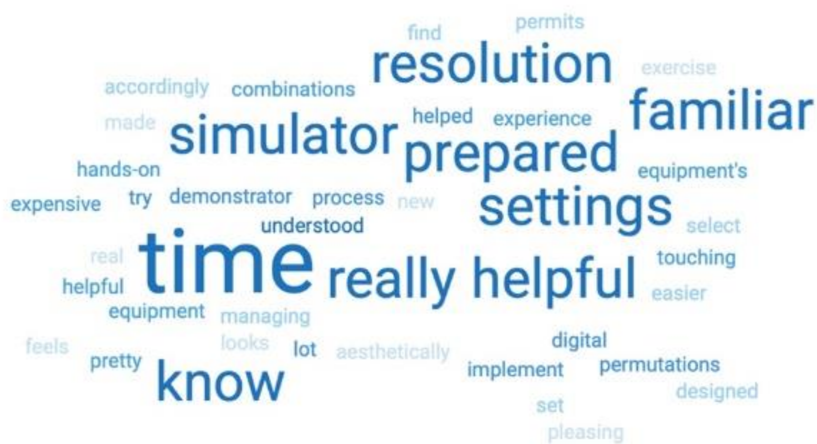


Figure 8. Word cloud of the student opinions

Conclusions

Integrating a digital demonstrator as an instructional tool for teaching students the correct setup and use of laser scanners proved to be helpful when applied in building construction management courses at the Georgia Institute of Technology. Testing documented that students found the demonstrator easy to understand and beneficial when first exposed to a FARO laser scanner. Students could quickly transfer the experience gained with the digital prototype to the setup of a physical scanner. Those students who completed full training on the digital demonstrator were able to set up the physical scanner more quickly than those with limited access to the prototype.

This experiment measured the success of a digital demonstrator in augmenting student exposure to a physical version of the same equipment. The same digital demonstrator could be applied as a replacement for a physical tool when access to costly equipment precludes such use in the classroom setting. The digital demonstrator was designed to provide students with a data set equivalent to what they would receive from a physical scanner. This makes it possible to prepare students for laser scanning using only the demonstrator. It is therefore recommended that the digital demonstrator be tested with students who do not have access to a physical scanner. This future research might include remotely offered instruction.

This research was limited to a single-use demonstrator. It is anticipated that similar success would be possible with digital demonstrators of other technology equipment in many areas of STEM education. Extension of the lessons learned from this study should be tested using other technologies standard in construction education. The demonstrator was designed to be used on a laptop computer screen. Several students did not bring laptops to class and relied on their smartphones when interacting with the digital demonstrator. This introduced unintended impediments to interacting with the online prototype. Future work would involve building a mobile version of the digital demonstrator to enable increased access. This study was also limited to a small student sample size. Expanding the sample size and supplying students with laptops should be considered to examine this topic further. Physical scanners other than the FARO model should also be included in future studies to validate compatibility with a wide range of scanners.

References

Aronsson, S., Artman, H., Brynielsson, J. *et al.* (2021). Design of simulator training: a comparative study of Swedish dynamic decision-making training facilities. *Cogn Tech Work* **23**, 117–130. https://doi.org/10.1007/s10111-019-00605-

Ebrahim, M. A. B. (2015). 3D laser scanners' techniques overview. *Int J Sci Res*, *4*(10), 323-331.

Kriz, W. C. (2003). Creating effective learning environments and learning organizations through gaming simulation design. *Simulation & Gaming*, *34*(4), 495-511.

Lewis, C., Polson, P. G., Wharton, C., & Rieman, J. (1990, March). Testing a walkthrough methodology for theory-based design of walk-up-and-use interfaces. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 235-242).

Mahatody, T., Sagar, M., & Kolski, C. (2010). State of the art on the cognitive walkthrough method, its variants and evolutions. *Intl. Journal of Human–Computer Interaction*, *26*(8), 741-785.

Ratvasky, T., Barnhart, B., Lee, S., & Cooper, J. (2007, December). Flight testing an iced business jet for flight simulation model validation. In *45th AIAA Aerospace Sciences Meeting and Exhibit* (p. 89).

Tiffen, J., McCormik, E. (1986). "Industrial Psychology," *Unwin Books*

Wolffe, G. S., Yurcik, W., Osborne, H., & Holliday, M. A. (2002). "Teaching computer organization/architecture with limited resources using simulators." *Proceedings of the 33rd SIGCSE technical symposium on Computer science education* (pp. 176-180).