Creating Virtual Environments in Support of On-line Problem-based Learning

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Abstract: This paper describes the development and comparative evaluation of applying terrestrial based LiDAR point clouds and photos to construct virtual field trips for an online Geodesign methods course. The results show that while virtual reality cannot fully replace immersive real-life experiences, it does have the potential to augment shared experiences in an online class environment, despite the current usability, cost, and hardware barriers.

Keywords: Online education, problem-based learning, virtual field trips.

1 Introduction

This is a descriptive paper that reports the process and results of a comparative approach to applying terrestrial based LiDAR point clouds and photos to construct virtual field trips for an online Geodesign methods course at the University of Wisconsin-Madison. The purpose of this research is twofold: 1) to develop a workflow to rapidly create virtual field trips to support place-based problem-based learning in an asynchronous online learning environment and 2) to comparatively assess various virtual field trip delivery mechanisms. LiDAR was chosen because, as LIN & GIROT (2014) and URECH (2019) documented point clouds are more efficient use of available memory, thus providing smoother virtual experiences for existing site representations. The length of this paper does not allow for a deep debate regarding the veracity of online education in the design professions. Instead, we focus on the potential uses of virtual environments in facilitating students' shared understanding of specific urban contexts within place-based design problem solving and methodological instruction, specifically design quality indicators of walkability in this study.

The aims of this course enhancement were to provide a place-based virtual field trip and assess two virtual field trip navigation strategies – browser and virtual reality headsets. Over the past several decades, higher education has seen increased interest and investment in online education. Universities have embraced online education to adapt to the changing economic and competitive landscape of higher education. Indeed, they seek to expand their presence, invest in technological innovation and respond to budgetary constraints (GEORGE 2017). Web technologies have led to the development of increasingly sophisticated online, interactive learning environments – facilitating interaction, work, and communication in approaches similar to traditional face-to-face learning environments (GARCÍA PEÑALVO et al. 2011, HEW & CHEUNG 2013). Despite the proliferation of online learning in higher education, it has seen limited implementation within landscape architecture because the traditional mechanisms used to facilitate, field trips and site visits, the very essence of problem and place-based nature of design studios have been difficult to replicate in an online environment. However, virtual reality (VR) has begun to effectively make its way into traditional face-to-face studios to great effect immersing students in their design solutions and understanding remote sites (CHAMBERLAIN 2015). Problem based learning (PBL) is a core pedagogical

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strategy used in landscape architecture studio courses, one that utilizes a learner-centered approach to develop a shared understanding of place that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem (SAVERY 2006). As a result, online courses have often been limited to technical skill development, general education, or entry level survey/lecture courses; however, recent discussions illustrate landscape architecture education is beginning to move some courses and degree programs online (PRITCHARD et al. 2018). Emerging virtual design studios (VDS) research has demonstrated online learning's capacity to facilitate learning and collaboration in design activities via online environments (KVAN 2001). Yet, several questions remain regarding two critical aspects of transitioning landscape architecture to design education online. First, how do we create shared online experiences to drive problem-based learning within context dependent methodologies? Second, how do we efficiently create immersive, shared, place-based experiences to facilitate student's understanding of the context of ideas, policies, landscapes, and the built environment within virtual environments?

1.1 Course Background

The course curriculum, VR content creation, course design, and assessment were all led by the authors. The primary author was responsible for course curriculum and content while the secondary authors were responsible for VR content creation and online course design, respectively. The Geodesign Methods, a three-credit course, was created as part of the University of Wisconsin's Geodesign Program, an asynchronous 12 credit post-baccalaureate professional certificate. Hence, students would be virtual students, the digital equivalent to non-resident distance education students (ROBERTS & HUNTER 2011). The program was created to introduce students to Carl Steinitz's Geodesign Framework (STEINITZ 2012). While many Geodesign courses, workshops, and programs focus on the process and products of Steinitz's framework, this program was designed to also provide opportunities to learn and apply skills, methods, and technologies through problem-based learning. Indeed, this course was intended to survey supporting research design and methodologies, including the technological 'how to' for each model within his framework. The course was not intended to be a button clicking, software instruction class. Instead, following the principles espoused by DIBIASE (2018), the course utilized weekly PBL projects, linked to specific models, while using applicable methodologies, and technology.

1.2 Pilot Project – Walkability

This pilot project focused on walkability, as a problem-based STEINITZ'S Geodesign process. The walkability assignment and associated GIS and virtual fieldtrip evaluations were completed as a portion of the model step, as students were asked to evaluate the walkability function of the site (STEINITZ 2012). Walkability was chosen because it requires the integration of technical mapping and contextual design qualities. Technical mapping consisted of pedestrian network connectivity and service shed assessments of key student defined destinations (e. g., coffee shops, food services, and bus stops), using ArcMAP network analyst and Madison's sidewalk network dataset. To assess contextual design qualities, a virtual environment was created using LiDAR data so that online students could assess design quality indicators of walkability (COOK et al. 2014), which typically requires being physically present in the space. Hence, the need for shared immersive experiences.

2 Research

2.1 Creating a Virtual Field Trip Environment

To collect the data for the VR landscape architecture project, the team employed a FARO Focus S120 terrestrial LiDAR scanner. The LiDAR scanner is a terrestrial-based, phase-shift scanner, and collects samples at angular increments. For this project, the team operated the scanner at a resolution of 44 million points per scan with a quality setting of four (four samples per angular increment), for a time of 12 minutes per scan. The team performed 89 total terrestrial-based scans of the area, for a raw count of approximately 3.9 billion points. The team used FARO SCENE to combine the individual scans into a single 3D point cloud and remove duplicate points, people, and vehicles. The point cloud was then exported to a XYZ ASCII text file format. After exporting the data, the team processed the XYZ files through two different custom data pipelines in preparation for rendering via an Oculus Rift CV1 head mounted display (HMD) (TREDINNICK et al. 2016) and on a desktop PC with an internally developed WebGL based renderer within the Google Chrome web-browser. Each pipeline processed the LiDAR data into an octree, a common spatial subdivision structure in 3D computer graphics (MEAGHER 1982). Additionally, high-resolution panoramic photographs, were paired with the original 3D location of the scan. The team incorporated these panoramic images with the processed point cloud data to allow a user to view both point cloud data (Figure 1), as well as the high-resolution panoramic photograph when a user navigates onto an icon that represents a scan location (Figure 2). Once the simulations were created, they were included within a Learning Management System (in this case Canvas) for student delivery. Students navigated the virtual environment using the joystick controls of the touch controllers associated with the HMD. Users were able to freely walk and look around their environment. Students navigated the web scene using traditional gaming keyboard controls (i. e., W and S for forward and backwards respectively and A and D to move left and right, respectively and mouse while holding down the left mouse button to look left, right, up, and down.)

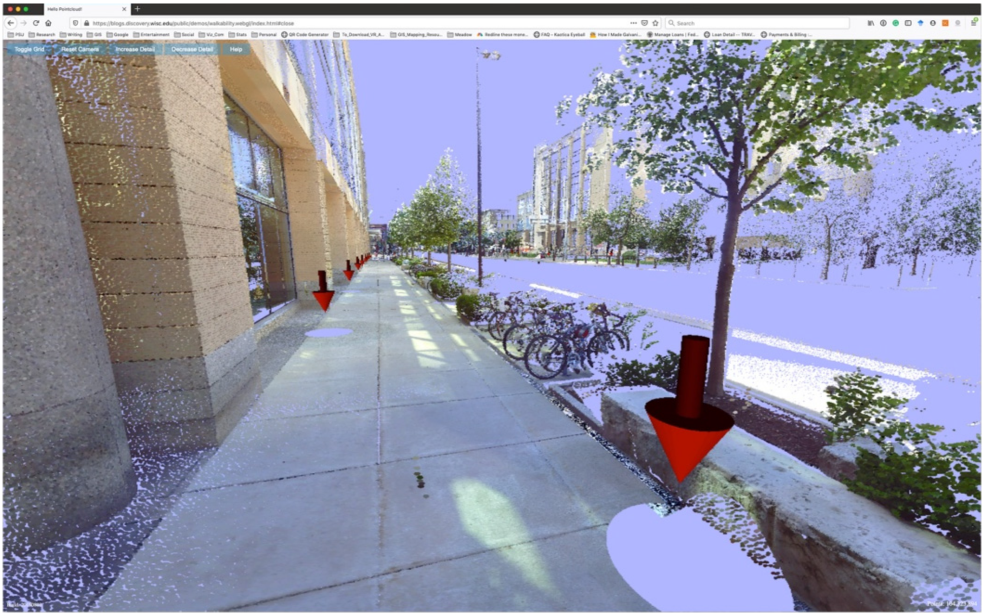

Fig. 1: Point cloud web scene navigator in Google Chrome

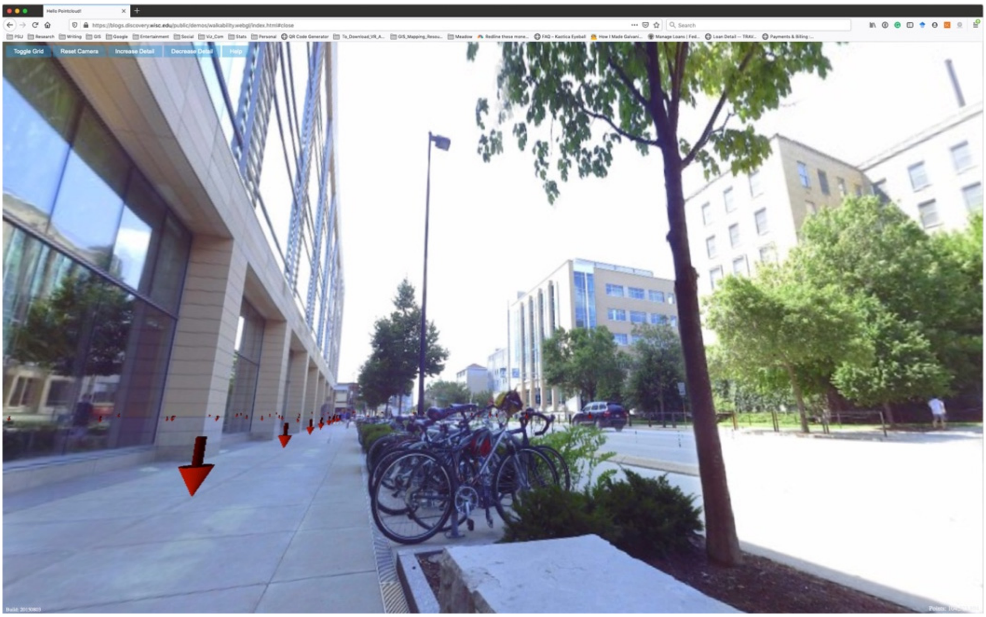

Fig. 2: High-resolution panoramic

It is worth noting the students who participated in this pilot study were in-resident students. The University of Wisconsin-Madison Institute for Discovery's Virtual Environments Group (formerly the Living Environments Lab) provided a controlled pilot study space, computers, and Oculus Rift CV1 HMDs. However, the course was intended for ex-situ virtual students, please see Section 4 *Conclusion and Outlook* for discussions regarding the implications of ex-situ virtual field trip hardware need implications.

2.2 Assessment Methodology

Our method of course enhancement evaluation primarily relied on student questionnaire surveys and secondarily on informal student interviews and participant observation. Note, because this project was a course enhancement effort, no specific standardized usability assessment methodology was used. However, it was loosely based on initial pilot focus group user assessment (MONAHAN et al. 2008) and upon completion of the pilot several interesting results emerged, which are discussed below. Future research should use assessment methodologies that assess both the learning potential (JANDA et al. 2004) and usability of the various virtual fieldtrips delivery approaches (GABBARD et al. 2006). Eleven graduate students participated in the pilot. The students were divided in half, the first group of students used VR headsets while the remaining students used the web-interface, and after 20 minutes they switched. Upon completion of this exercise the students completed a survey. The survey was segmented into two topical areas: VR usability (Table 1) and learning value of VR (Table 2).

Table 1: VR usability survey questions and associated response scales

Questions	**Every day**	**Regularly**	**A few times**	**Once**	**Never**
Have you experienced virtual reality with a head mounted display in the past?					
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I felt disoriented and/or nauseous while wearing the headset?					
Overall, I found the web-based viewer easy to use.					
Overall, I found the head mounted display viewer easy to use.					
	Traditional techniques (i. e., field work, on-site)		Web-based viewer	VR head mounted display viewer	
Overall, I would prefer for walkability tasks.					

The VR usability portion of the survey contained five questions covering students experience using VR, VR usability, and preferred method of engagement. The learning value portion of the survey contained three questions regarding each virtual field trip interface's (i. e., VR HMD and web-interface) value in understanding design quality indicators, one question regarding interface preference, and two open-ended questions addressing the potential of VR in online education and additional comments and questions. Five observers noted student commentary and issues that arose during participant VR use. At the end of the exercise the students and observers engaged in semi-structured focus group to discuss reoccurring issues and opportunities in more detail.

Table 2: Learning value of VR questions and associated response scales

Questions	Yes	No
Did your participation in the immersive headset VR simulation enhance your understanding of qualitative factors of walkability?		
If yes, how, and if not, why not?		
Did your viewing of the web viewer VR simulation enhance your understanding of qualitative factors of walkability?		
If yes, how, and if not, why not?		
	Web viewer	**Headset**
Did you prefer one version of the simulation over the other (i. e., immersive headset version vs web viewer)?		
Please explain.		
As you think of your previous and future planned learning experiences, in what learning situations do you think this type of VR simulation could enhance your learning? Either immersive headset or web viewer please specify in your answer.		
Please provide any additional comments or suggestions you have about your VR simulation learning experience?		

3 Discussion and Lessons Learned

Similar to WISSEN HAYEK et al. (2019) findings, the results of this study show that the VR HMD leads to a perceived higher level of involvement, a stronger feeling of being present, and a higher perceived level of realism. Indeed, through the surveys and group discussion, students unanimously described the VR HMD experience as more immersive, albeit, more confusing to navigate. This is not surprising since none of the students had previous experience with VR HMD and were more familiar with web scene navigation. However, what was surprising was that ten of the eleven students, on average, completed their tasks three minutes faster using the VR HMD, despite their perceived difficulty in using the VR controllers for navigation. All students experienced various degrees of VR HMD motion sickness. During the semi-structured focus group discussions, it was determined that the motion sickness documented by previous research (HETTINGER & RICCIO 1992, NICHOLS & PATEL 2002) was compounded by navigating a continually redrawing point cloud in real-time. As a result, no student used the VR headset for more than ten minutes. Despite these limitations and student preference for in-person site visits their enthusiasm remained high for the VR experience. All students were less interested in the web scene navigation and suggested it offered little more than a video or series of photos would offer. The students went on to note the utility of the VR HMD in both online and in-person courses for shared immersive experiences to locations discussed within a variety of course types, but that are unvisitable for a variety of logistical reasons. Finally, the students collectively suggested three VR HMD improvements in both the surveys and discussions. First, the user should be programmatically locked to the ground so as they navigate the scene, they do not inadvertently become airborne and further disoriented. Second, the user should be able to utilize selectable and programable eye heights to offer the perspective of various user groups, such as children or wheel-chair users. Third, the user should be able to set programmable speeds to better understand how walkable various street crossing are for differently abled and mobility challenged pedestrians.

4 Conclusion and Outlook

The use of LiDAR within landscape architecture is not new, neither is online education. In fact, LiDAR is commonly used to remotely analyze expansive landscapes (MURTHA et al. 2018, PRICE & GORDON 2016). Additionally, the emergence of online education in landscape architecture has introduced novel approaches to the virtual design studio (GEORGE 2017, 2018; HERBERT et al. 2011; MARLOW 2009). However, there are still significant barriers to using VR HMD displays as an online virtual field trip experience. First, there is the logistical and economic burden for virtual students because VR HMD displays are still niche hardware. While the cost of VR HMDs has decreased, streaming a point cloud still requires significant investment in computer hardware, even if the VR HMD virtual field trip like the one outlined in this paper requires less bandwidth and hardware than traditional solid three-dimensional, textured models would. These advanced hardware requirements would place undue logistical and economic burdens on economically disadvantaged students. Second, VR HMD still have locomotion and usability issues to resolve. There is still a need for virtual students from varying backgrounds and contexts to share placed-based learning experiences within online courses. As a result, we only recommend the use of VR HMD field trips under two conditions. The first condition necessitates that the hardware is: more affordable, ubiquitous, or a university-supported loaner program is enacted as to not pose a significant logistical or economic burden on the students. The second condition is that the course is a shared immersive experience, such as the walkability design quality indicators presented earlier in this paper or the mobility challenges presented by the student discussion on walkability and VR. Due to the issues discussed and despite the students' indifference to the web scene virtual field trip, future systematic research is necessary to revisit the immersion experience, assess learning potential, and to continue assessment of VR HMD drawbacks

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