Scan, Immerse & Learn: VR Enabled Field Study

Hope Hasbrouck[1], Robert Stepnoski[2]

[1]University of Texas at Austin, Texas/USA · hhasbrouck@austin.utexas.edu
[2]University of Texas at Austin, Texas/USA · rob@austin.utexas.edu

Abstract: 3D scanning technologies supported the generation of a virtual 3D environment designed to advance spatial and technical learning at a fundamental level for landscape architecture students after COVID-19 safety protocols rendered a studio site inaccessible. The paper discusses accessible workflows for integrating site capture data with landscape information and representation models. Each model derived from the point cloud is tied to specific learning objectives ranging from analysis to qualitative evaluation and spatial experience. The studio continues to use the scanned site to advance representations and analysis now that COVID-19 restrictions have been relaxed.

Keywords: Virtual environment, 3d scanning, site capture, technology acceptance, experience age

1 Introduction

Imagine conducting field studies for an inaccessible landscape. What is necessary to imprint a sense of place, a feeling of enclosure, and convey the technical idiosyncrasies of place? Design faculty confronted this question in the Fall of 2020 when COVID-19 safety protocols rendered a studio site inaccessible. The paper discusses faculty efforts to apply proven scanning and Virtual Reality (VR) technologies to prepare experiential site documentation. The faculty sought to develop a representation model that best simulates students' on-site presence and spatial experience to support their first landscape architecture design studio. The faculty found a solution in the visual feedback from body movement in an immersive environment called VR (AARSETH 2001). The value of this discussion for design instructors is the connection made between the technological affordances of VR and the studio's organization and pedagogy, including student learning objectives in this “age of experience”.

The faculty believed VR was a tool to keep students engaged with the site and conditions during a virtual studio. The studio used online group discussions and daily whiteboard postings combined with VR-based activities. The variety of tools was our solution to maintain or elevate student engagement. We adopted Dalgarno and Lee's position that VR can address educational challenges in the experience age, which will lead to increased student engagement (DALGARNO & LEE 2010).

2 VR for Field Study

The first-semester design studio engages site design at the most intimate of scales, the body scale. The project is a courtyard on a university campus defined by four architecturally significant dormitories for honours students. The project typically begins with a site visit and field studies where the students document the formal and physical relationships at several scales.

Journal of Digital Landscape Architecture, 7-2022, pp. 318-326. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-724-3, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537724031.

Covid-19 safety requirements for university residence halls made a site visit impossible, so faculty aimed to provide a virtual body scale experience for field study. The faculty team employed the 3D scanning process to build a digital equivalent of the site. The models derived from the point cloud supported specific project milestones and learning objectives. It was essential to faculty that the workflows and tools were as invisible or instinctive as traditional representation tools and did not redirect students' focus from analysis and design iteration to tool mastery.

3 Defining Site and Scale for Study and Analysis

The studio employed Carl Steinitz's framework for design to guide the students through the project phases and to frame the questions they should be asking while advancing the project (STEINITZ 1995). Phase one entailed making a landscape representation model. Steinitz defined a representation model as depicting a landscape including content, boundaries, space, and time (STEINITZ 1990, STEINITZ 1995). Building off Steinitz's definition, faculty posit that a site's material composition and physical features determine a site's character. Its intersection with landscape systems determines the site's complexity. In the studio's site inventory phase, we require rendering a site at all scales where relationships between the landscape architectural project and the site's physical, biological or social systems are present. The value of those relationships is determined by the proposed program's agenda, thus determining the geographic extent of the future landscape architectural project. We instill the belief that a site is known, drawn, analyzed, and eventually resolved at the scale of all proposed relationships, including physical, biological, or social. Students were expected to collect data and produce representation models at all spatial and temporal scales. The scales are loosely translated into region, territory, site, and body.

Geographic Information Systems data for the study area was readily available, and students had unrestricted access to the region, territory, and the site's perimeter for inventory and mapping. The on-site field study was conducted in a VR model. The model was composed of a point cloud generated by a 3D scanning process. The expectations for the model and the entire VR experience must aim to provide a sensorial experience that captures the material, character, and texture of a place. The students had to do without taste, smell, and sound, but the essentials of perceiving distance, enclosure, and volume were possible in VR.

4 The Scanning Process

The faculty employed traditional photographic techniques to document the courtyard identifying significant topographic conditions, building entries, stairs, retaining walls to determine the ideal laser scanner locations. Initial photographic documentation and review were crucial to determining 3D laser scan locations for maximum coverage of significant features. What the scanner does not see will not appear in the 3D virtual model.

The thirty-four scanning locations were used to provide adequate coverage. The laser line-of-sight successfully captured trees, benches, statues, monuments, walkways, and stairs to each perimeter building. The Z+F Color 3D Laser Scanner was positioned on a surveyor tripod at six feet (1,83m) above ground level. Each scanning position was approximately thirty-five feet (10.668 m) in front of the next (Fig. 1), even though the scanner has a maximum scanning distance of four hundred feet (121.92 m) (ALMUKHTAR et al. 2021). The desired precision required adequate overlap of each scan. Surveyor targets were distributed throughout to ensure accuracy and triangulation for the post-processing software. The targets aided the manual registration method if a scan was misaligned (LENDA et al. 2019). Fortunately, the team post-processing was successful after the first run, with all 3D laser scans registered without error.

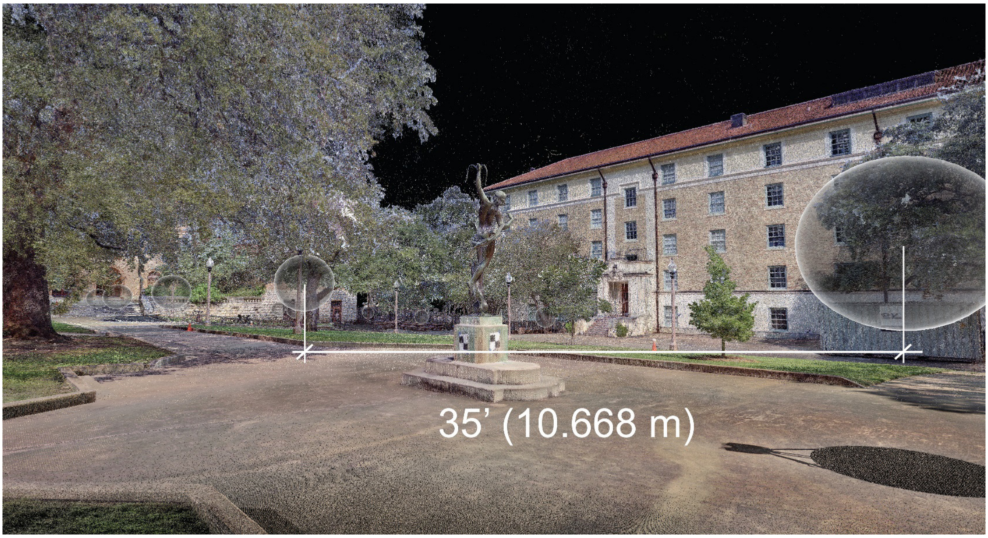

Fig. 1: 3D Point Cloud with scanning stations at 35' (10.668 m) intervals along axis

The sizeable Light Detection and Ranging (LiDAR) datasets were accompanied by 360-degree panoramic images from each scanning location. Autodesk Recap Pro and Cloud Compare were used to index and register the laser scans into a high-density 3D point cloud model. The resulting point cloud model was classified into several groups: ground plane, buildings, and high and low vegetation. The ground plane was exported to generate a topographic model and contours. We compared the topographic model with historic topographic data provided by the City of Austin to validate the dataset.

The point cloud model was exported as a laser file type and run through the “decimation” process to simplify the number of points in the point cloud. Decimation was necessary because Unity3D works best with a limited number of points for a point cloud. In this case, not more than 15 million points. The decimation grid spacing can be set from 1mm to 100mm during the export process. The courtyard required several iterations of grid spacing settings for qualitative testing by students in VR. The decimation grid controls the number of points to import by specifying the smallest cubic volume that a single point can occupy. Lower values improve the quality of the point cloud (Autodesk) and increase the file size. 10 mm, 25 mm, 50 mm, and 100 mm grid spacing settings were used as a comparison for the students to test the effect decimation has on perception. All students preferred the 10 mm grid.

Importing the cloud into Unity3D required PointCloudXR (LJUNGBERGSLABORATORIET 2019) scripting foundation source code, written in C#. The 3D point cloud model worked most efficiently, with the volume of points being less than fifteen million. The open-source software LASTools converted each LAS point cloud file into LAS 1.2 format to operate within the PointCloudXR Unity environment. The Unity3D, LAS point clouds were opened using the VR workstations resident in our VR Lab. The VR lab consists of several dual Intel Xeon CPUs, 196 GB RAM, triple Nvidia Quadro GPU systems running the Vive Pro headset to process and run each point cloud. Nvidia GeForce GTX 1070, 1080, and 1080Ti systems were tested and worked successfully on all workstations. Students could freely interact and explore the Unity 3d point cloud environment.

5 Derivative Models from Point Cloud

The studio project was organized into three phases: site inventory and analysis, schematic design, and design development which aligns with the inquiry sequence of Steinitz's framework. The point cloud data structure was versatile enough to generate three models to fulfill specific project tasks. The initial point cloud imported in CAD software supported measure and analysis. The point cloud imported into Unity3D supported the VR sensorial walkthrough for field study and analysis. The point cloud later became the context for student projects augmented by a dynamic renderer for evaluation and presentation models at the end of the project.

5.1 Point Cloud for Measure and Analysis

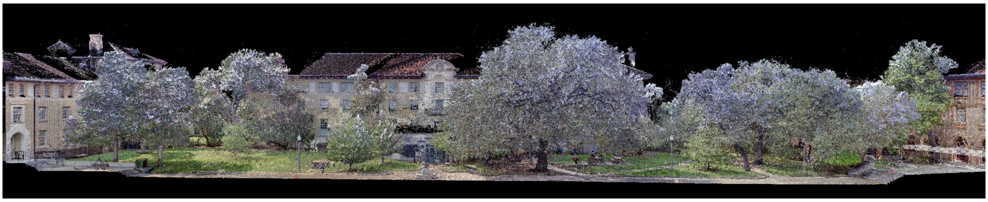

Fig. 2: Cross Section looking North in Recap Pro 3D Point Cloud model from the 3D scan

Once imported into ReCap, the point cloud (Fig. 2) did not provide the desired sensorial experience but was necessary for generating several derivative models for the students. The point cloud was registered and indexed using Recap Pro. The faculty saw the ReCap model as a transitional state supporting initial steps in the project's site inventory and analysis phase. The ReCap model referenced by Civil 3D generated an existing surface model contours for analysis, aided in base document generation, and sized and located the significant heritage trees on site. Students were given the project brief and introduced to the site through the ReCap model and the high-resolution panoramic photographs generated during the 3D scanning process.

5.2 VR Model for Sensorial Extent

The immersive experience of the courtyard was the point cloud in Unity3D using the HTC Vive. Covid safety protocols dictated room occupancy, so four VR Vive stations accommodated four students and a socially distanced spotter (Fig. 3) to walk the site virtually. The Unity3D model was for field studies that included ground-truthing the courtyard's as-built conditions, spatial analysis, but most importantly, experiencing the spatial volumes of the courtyard, defined by both the buildings and the many heritage trees. Secondary activities directly involved integrating visualizations of technical and formal organizational principles in the model to aid analysis and perceived spatial organization. Spatial ordering principles like symmetry driven by axial alignments between buildings were visualized in the VR model. Slope analysis was displayed and experienced through immersive walking reinforcing perceptions of surface gradients, highlighting areas of critical concern for accessibility. The Unity3D VR model was helpful during the inventory, analysis, and schematic design phases. The hope was that students would return to the Unity 3D VR point model and panoramas for reference as much as possible, just like they would if the site was accessible.

Fig. 3: Student navigating Unity3D Point Cloud model in VR

5.3 Design Proposal to Dynamic Renderer

As the project advanced, the point cloud became the context for student projects. Student paraline and surface models were developed in Rhino and imported into Enscape3D (Fig. 4). Enscape3D, a dynamic renderer, when integrated with Rhino, populates the model with dynamic vegetation, entourage, and environment systems for a direct VR experience. The direct path from the design model to a dynamic venue for evaluation elevated student engagement with the tools and each other. In subsequent studios with less restrictive COVID protocols, we used Enscape3D with headsets in the final review. VR integration for interrogating design proposals was revelatory for the students and jurors.

Fig. 4: Student Final Project in Enscape3D

6 Discussion

Capturing a highly accurate and detailed 3D model of the site was necessary for field study and meeting learning objectives. The project brief demanded a sensory experience to tune student observation skills. While 3D laser scanning methods have been around for some time, our efforts set achievable parameters and accessible workflows for repetition in a classroom. The compelling reason for using VR as a tool for instruction was to meet the students' experiential needs in a way most students understood (WADHERA 2016). The 3D point cloud within the Unity3D platform experienced in VR set expectations and opened possibilities that ushered students toward embracing the Enscape3D environment. The logical and direct workflow appeared to connect with students prompting group interaction with all projects in the VR environment.

The LiDAR color laser scan was chosen over black and white because the color generated a convincing digital twin (POUX 2020). Black and white laser scans are suitable only for measurement, ground-truthing, and derivative mesh models. The color laser scans brought the students as close to an actual sensory experience as possible. Material color, vegetation texture, ground plane, and the perimeter buildings became essential talking points for the student design projects. One student remarked on the significant discovery of basement-level light wells underrepresented in the historical documents. The technical grading solution would be incorrect if that discovery were not made during the VR walkthrough.

VR navigation often includes flight. The audience is presented with the opportunity to access the inaccessible. In the case of our studio, residence halls prohibit access to outsiders, so views from terraces, reading rooms, or dorm rooms are not possible. The VR environment provides opportunities to test design decisions or evaluate existing conditions from carefully considered viewpoints from the building's interior (LAU & LEE 2015).

The frequency or distance between the points and the display size of the points are two cloud attributes that greatly influence the legibility of space and volume, like the effects of pointillism where the audience's mind blends the points into a broader range of hues and values. Adjusting the size of the points within the cloud brought the ground plane, building façade surfaces, and tree canopy into sharper relief. Students expressed a real sense of place when space was compressed between the tree canopy and the ground plane. Several students had no idea how large the heritage trees were until exploring the point cloud model. Those impressions were then tested using the measurement tools, not unlike how one would pull out a tape measure during a field study.

Studio instructors intentionally aligned the phase of design inquiry with scale, data structure, and representation models. The learning objective was to critically select representation models to support and advance design inquiry. Geographic models for small-scale investigation partnered with geometric models for large-scale studies. The initial geometric model was the Unity 3D point cloud which became the immersion model providing the sensory experience of being on-site. As students progressed through the design phases, data structures advanced topologically. The projects concluded with critical evaluation in VR with Enscape 3D, including overly simplified material, texture, and environmental effects like sun, shadow, or wind suitable to the student academic level.

There is no substitute for faculty-led in-person site walks to sharpen student observation skills and prompt the development of the mental model that connects measurement with the sensory experience of place. However, the digital-twin accelerated the identification of spatial compression and volumetric limits simply through digital abstraction. Therefore, the digital twin met all faculty expectations. Scanning efficiently used time and resources to generate the twin. The color scan supported by iterations of point size and sampling resolution together produced a model that convincingly modelled enclosure, ground plane, and vegetation. It rivalled drawings in revealing the particularities of the courtyard.

Most importantly, the quality of the point cloud model made the boundary and edges of spatial volumes legible. This sensory experience in the initial VR model set expectations for the sensorial VR experience of the final design proposals. The students were given an opportunity for a one-to-one comparison.

Faculty expectations of students repeatedly returning to the ReCap and Unity 3D models were not met. We attribute this to several factors; reluctance to return to campus during COVID, bandwidth limitations to access files from off-campus, and a general self-conscious trepidation of using VR. Trepidation repeatedly continued with jurors and students reluctant to use VR in group settings. Conversely, individuals with gaming experience had no difficulty using the VR tools in public settings. A solution to VR reluctance (HU-AU & LEE 2017) was for one savvy user to navigate projects during critiques responding to juror requests and directions. This technique redirected attention away from the tool and social awkwardness toward the design proposal and student work.

7 Conclusion

Embracing VR in the experience age (HU-AU & LEE 2017) has demonstrated the potential to deliver compelling learning opportunities in design. VR provided one studio a solution to a unique instructional situation during a pandemic. It was clear to faculty that the benefits of VR surpass the limitation presented by the pandemic. Faculty approached the tools with caution, knowing that "just because you can do it does not mean that you should." The solution tied learning objectives and the project conceptual framework to the digital representation models. The tools were needed to advance student inquiry, and they did. Evidence of mastery was mixed during the first fall semester of the pandemic. Honing the mental model that connects measurement with the sensory experience of the place was mixed across the cohort of students. When the studio repeated the project the following year, and students had access to the courtyard and the digital model, the faculty saw improvements in comprehending scale and spatial boundaries. We attribute student success to the purposeful redundancy of representation models where students move back and forth between life and VR, 3D and 2D, small scale to large scale. Purposeful redundancy is a foundational tenant for introductory design pedagogy.

Future studios shall bring augmented reality to the site, making the formal and technical analysis visible for necessary field study and spatial literacy.

References

AARSETH, E. (2001), Virtual worlds, real knowledge: towards a hermeneutics of virtuality. European Review, 9 (2), 227-232.

ALMUKHTAR, A., ABANDA, H., SAEED, Z. O. & TAH, J. H. M. (2021), Reality Capture of Buildings Using 3D Laser Scanners. School of the Built Environment, Oxford Brookes University, Oxford.

AUTODESK, Import Settings | ReCap | Autodesk Knowledge Network. https://knowledge.autodesk.com/support/recap/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/Reality-Capture/files/GUID-0AD00B15-777D-4519-AC58-51499BBCAA2E-htm.html (March 23, 2022).

DALGARNO, B. & LEE, M. J. W. (2010), What are the learning affordances of 3-D virtual environments? British Journal of Educational Technology, 41 (1). Section: 3-D VLEs.

FARO (2020), Target Placement When Using the Focus3D Laser Scanner. FARO Knowledge Base. https://knowledge.faro.com/Hardware/3D_Scanners/Focus/Target_Placement_When_Using_the_Focus3D_Laser_Scanner (Aug. 24, 2020).

HU-AU, E. & LEE, J. J. (2017), Virtual reality in education: a tool for learning in the experience age. Int. J. Innovation in Education, 4 (4), 214-222.

LAU, K. & LEE, P. (2015), The use of virtual reality for creating unusual environmental stimulation to motivate students to explore creative ideas. Interactive Learning Environments, Vol. 23.

LENDA, G., LEWIŃSKA, P. & SIWIEC, J. (Dec. 2019), Accuracy of Merging Point Clouds at the Maximum Range of a Scanner with Limited Possibilities of Target Placement. Archives of Civil Engineering.

LJUNGBERGSLABORATORIET (2019), PointCloudXR. 3D Remote Sensing Lab. Swedish University of Agricultural Sciences, Umea, Sweden.

POUX, F. (2020), "How to represent 3D Data?" Towards Data Science. May 11, 2020. https://towardsdatascience.com/how-to-represent-3d-data-66a0f6376afb (Aug. 24, 2020).

STEINITZ, C. (1990), A Framework for Theory Applicable to the Education of landscape Architects (an Other Design Professionals). Landscape Journal, Fall 1990, 9 (2), 136-143. doi: 10.3368/lj.9.2.136.

STEINITZ, C. (1990), Design is a Verb; Design is a Noun. Landscape Journal, Fall 1995, 14 (2), 188-200. doi: 10.3368/lj.14.2.188.

WADHERA, M. (2016), The information age is over; welcome to the experience age. Tech Crunch, May, Vol. 9. https.//techcrunch.com/2016/05/09/the-information-age-is-over-welcome-to-the-experience-age.