Distributed Site Analysis Utilizing Drones and 360-degree Video

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Abstract: This paper examines the use of drones mounted with a 360-degree video camera to facilitate site analysis of remote sites in instances where it is not feasible for an entire group of students to visit a site, and to provide the opportunity for repeated review of such sites. By utilizing drones and 360-degree video cameras, it is possible to provide students with an immersive virtual experience of a site that can be referenced continuously throughout a project. This research describes the use of 360-degree video to document a half-acre site. Students were asked to conduct a site analysis by viewing the video using Google Cardboard and a computer. The site analyses produced by the students were compared to determine their effectiveness, and a focus group was held with students who participated in the experiment to gather feedback on the experience of using the 360-degree video. The results of the experiment suggest that the technique can be used effectively to conduct a general site analysis, and is especially effective when coupled with additional resources about a site. It is concluded that students are able to successfully conduct a remote site analysis by utilizing this method.

Keywords: Drone, 360-degree video, virtual reality, site analysis, site documentation

1 Introduction

There is inherent value in having design students work on projects outside of their local geographic region and culture. This includes providing students with the opportunity to accumulate a diverse set of experiences, grapple with unfamiliar challenges, and explore alternative worldviews and value systems (DAVE & DANAHY 2000, GÜL et al. 2012). While these benefits provide students with an opportunity to expand their learning, these types of projects often present significant challenges to institutions and instructors. Most prominent among these challenges are those associated with working on a site remotely distant from the university. When working on distant projects, it is often difficult or impractical for a program to send to the site all of the students working on a project because of the costs involved, and so alternative approaches have been explored to provide students with the opportunity to analyze a distant site. Likewise, it is often cost prohibitive, and would consume too much time, for students to repeatedly visit remote sites. This is problematic because one of the most critical phases of the design process is the site analysis, suggesting it is very valuable to explore methods to facilitate effective remote site analysis (ZIMMERMAN 2000).

Sometimes, programs will send a handful of students as an advance team that will visit and document a site for future study, analysis, and reference by students who were not able to participate in the site visit (SIMONS & KONDOLF 2012). While this is beneficial, and does provide a certain level of awareness amongst all the students of the characteristics of the site, it is not without important drawbacks. One of these drawbacks, is that the site becomes filtered through the eyes of the people who are able to visit the site. The particular set of interests and values possessed by members of the advance team, intentionally or not, introduces a bias into the documentation of the site. This filtering is then passed on and magnified

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throughout the design process as more and more students utilize the information. Furthermore, this deprives the students who did not visit the site of having the opportunity to conduct a truly thorough analysis of the site, as much of the analysis has already been done to a preliminary level by the students who visited the site. Therefore, this method is also pedagogically suspect by privileging some students over others in their educational opportunities. Another major problem includes the inability to conduct multiple site visits, so students have to rely on just a single visit and whatever documentation was collected at that time.

Another approach that has been used is to rely on digital artifacts of the site question to conduct a site analysis. This approach has shown promise because of the wealth of information that is available online from which to conduct an analysis. This includes resources such as GIS data sets, Google Earth and other satellite imagery, as well as the creation of 3D models or other digital artifacts from a site (WATTS & TORRES-BUSTAMANTE 2014). However, research has shown that utilizing this type of information is not as successful as we might hope, as students typically don't have as high of a level of spatial awareness of the site as when they are able to physically visit the site (GEORGE & MICHAEL 2012). Research has demonstrated that a 3D model can be used to successfully convey spatial data at a similar level to a physical site visit, but the requisite investment of time and other resources to create a 3D model of a site normally makes this approach impractical, especially as the size and complexity of a site grows (HAVAL 2000, BISHOP & ROHRMANN 2007).

Based on the promising example of the use of digital tools to conduct or augment the site analysis process, it was theorized that the use of a 360-degree camera to create an interactive and immersive video of the site would provide an enhanced spatial experience and provide the opportunity for students to virtually visit a site and create an analysis based off of their own observations, instead of relying on material gathered by other students. While it is recognized that a physical site analysis is always preferable to one mediated through technology, it is also felt that the benefits of enabling students to work on diverse geographic sites can provides sufficient benefits to warrant the use of a virtual site visit in order to facilitate the design project. If successful, the use of 360-degree video could enable students to more easily and effectively work on design project associated with remote sites in a resource-efficient manner, thereby increasing institutions ability to broaden their students' experiences beyond their local region.

2 Methodology

This research used an exploratory action research methodology. The initial stages of research focused on resolving the best method of capturing the 360-degree video. The camera used in the research is the commercially available 360fly camera. This camera was primarily selected because of its compact size and ease of use that made it ideal for testing. However, a drawback of the 360fly camera is the 120° blind spot in the nadir (the viewpoint vertically below the camera), which constrains the vertical height placement of the camera so as to avoid a large blind spot. Videos were created using the camera mounted on both an aerial drone and a terrestrial drone (a remote vehicle traveling overland), to assess which method would produce videos more accurate of the experience of being on a site.

Both types of drones had several affordances and constraints. The aerial drone provided comparatively smooth footage, enabled quick capture of a site, was not hindered by grade changes, and could provide higher-altitude context video of the site. However, the aerial drone had more difficulty navigating the site due to obstacles such as trees and poles, had to fly well above eye level for safe operation (~ 4 meters), required an experienced and qualified operator, and is more likely to be unavailable due to adverse weather conditions. In contrast, with the terrestrial drone the camera was closer to eye-level (1.1 meters), could be operated by someone without special training, and was easier to navigate around obstacles on the site. However, the video captured using the terrestrial drone was unsteady at time due to uneven ground plane conditions and special accommodation had to be made for grade change obstacles, such as stairs. After evaluating the required time and effort to capture the video, as well as the video captured using both drones, it was determined that the video captured using the terrestrial drone was preferable because of the more realistic viewpoint, greater manoeuvrability around obstacles, and ease of operation.

After capturing video of a site, a focus group was held with junior and senior-level landscape architecture students (n=10) to evaluate the effectiveness of the 360-degree video in conducting a site analysis. The students were asked to watch the video using a smart phone in a Google Cardboard viewer and also on a laptop computer with a 13-inch monitor. When using Google Cardboard, the students could reposition their view within the video simply by turning their head and looking up and down. When viewing the video on the computer, students could reposition the view utilizing the mouse. The site consisted of a half acre parcel located adjacent to a river. The site had two terraces, a boat launch, and some structures. The video was captured using a route that provided multiple passes over the terrain and enabled students to view the entire site from multiple positions and angles. The entire video was 5:06 minutes long. To assist in the analysis of the site, students were provided with a basic base map that showed property lines and structure locations.

The students were given one hour to produce a general site analysis of the site using the 360-degree video. The student's site analyses were then compared to a preliminary site analysis produced by the researcher to determine accuracy of the analyses and to identify consistent variations. Additionally, an unguided discussion was held with the students at the end of the focus group to gather the student's thoughts on the use of the 360-degree video.

3 Results

3.1 Comparison of Site Analyses

The comparison of the student's site analyses to the master site analysis showed that, overall, the students were able to conduct an accurate analysis of the site. The general structure of the site was accurately represented in the analyses, and in most instances appropriate conclusions were drawn (Figure 1). The students were able to identify the major features of the site, relationships between elements on the site, design opportunities (such as views and natural desire lines) and constraints (such as boundaries and poor terrain). Scale was accurately depicted, though positioning of some elements were off by as much as 2.5 meters, which was not unexpected as the students did not have a method to take measurements within the video, but had to rely on visually judging distances. Half of the students included more subtle observations, such as the presence of wind, intensity and direction of wind, and solar observations. A couple of students also made informed interpolations from the video, for instance one student indicated a strip along the river where the temperature was cooler due to the proximity of the water.

However, the students failed to note small details within the site. For instance, a 25 meter tall metal lantern on top a wooden post on the river bank was not noted by any of the students (the camera passed approximately 2 meters from the post). Similarly, a black gate was noted by all of the students, but none commented on the material used to construct the gate (metal). Combined with information gathered during the discussion with the students, it is clear that the resolution of the video was insufficient to adequately portray small details of the site.

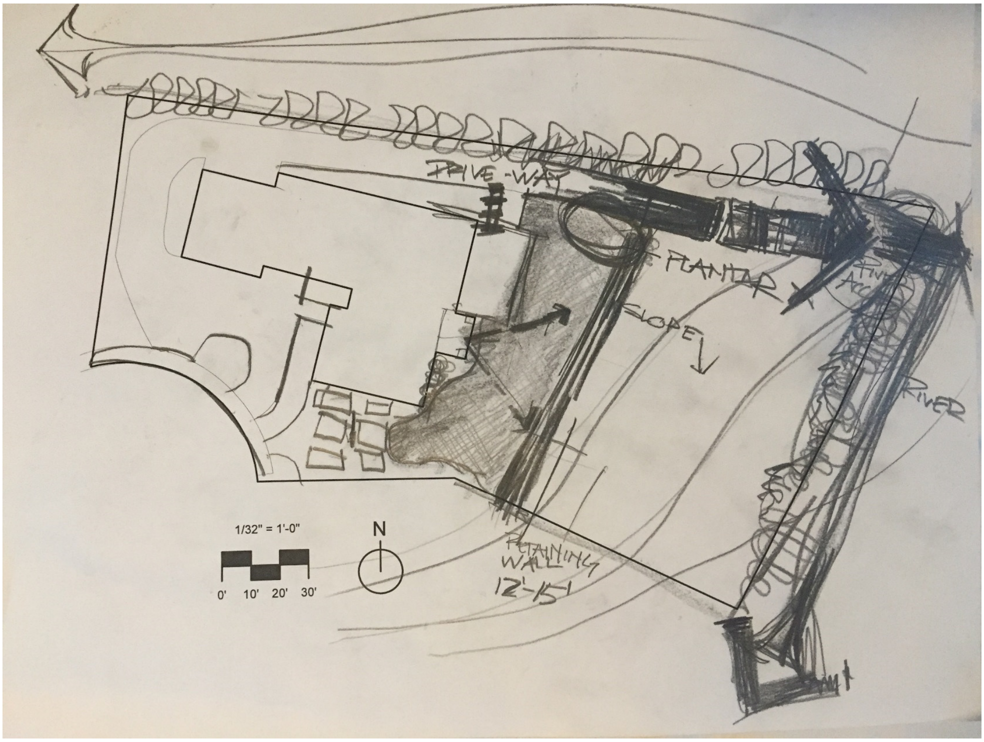


Fig. 1: An example of one of the site analyses produced by students using the video

3.2 Student Assessment

The results of the discussion showed that the students responded positively to the use of the 360-degree video to conduct the site analysis. The students reported that they preferred the 360-degree video to still photographs or single-perspective video of a site. Students reported that using Google Cardboard provided a very immersive feeling and created a feeling of being present on the site. For visualizing and experiencing the site, the use of Google Cardboard was much preferred over viewing the video on the monitor. However, the computer version was preferred for analysing specific elements of the site because they could simultaneously watch the video and take notes, something not possible with the Google Cardboard viewer, which requires the user to hold it up to their face to view the site.

The students felt confident that they would have been able to produce an effective design of the site using solely the 360-degree video. However, they felt that the use of this type of video would be especially valuable when paired with a physical site visit to enable them to revisit and re-experience a site while within the studio at the precise moment they might be grappling with a particular challenge in the design.

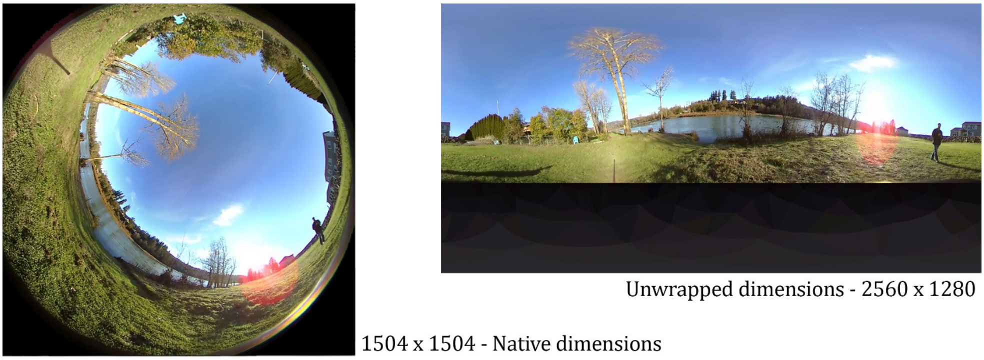
A surprising result of the discussion was the difficulty that students had in judging slopes on the site. They could easily identify large differences in the slope of the terrain, but struggled to identify gradual slopes, and to determine where exactly a slope started and ended. Another surprising result was that the students found it awkward to orientate themselves on the site in regards to direction. This finding was consistent across nearly all the students, who reported that, had it not been for the river providing a highly visible landmark, they would have found it difficult to orientate themselves on the site.

4 Discussion

This section discusses the technical and pedagogical aspects of utilizing a 360-degree video for site analysis, and suggests some preliminary recommendations regarding best practices. In considering the technical aspects of creating and using 360-degree video, the most critical shortfall was the difficulty students experienced in identifying and interpreting small details on the site, including objects and materials, but also subtle variations in the ground plane. It is probable that much of this issue could be compensated for through the use of higher resolution video, but consideration should also be given to pairing the video with still photography to provide multiple representations of important details on a site (ZUBE et al. 1987, WERGLES & MUHAR 2009).

Pedagogically, using the 360-degree video provided clear benefits to the students by being able to immersively experience a site. A criticism of utilizing advance teams of students is that the experience of the site is filtered through the eyes and values of a handful of students, and one of the objectives of utilizing 360-degree video was to reduce the amount of filtering that occurs when working on distant sites. Admittedly, some filtering still occurs because the drone is driven along a route determined by the operator, but it is believed that the amount of filtering was reduced by enabling students to have greater control of their viewpoint and focus and by utilizing multiple passes across the site to provide multiple views and experiences of the site. In this way, the experience of the site is mediated by the chosen path of the drone in as minimal of a way as possible.

The combination of a 360-degree video with an initial physical site visit is an especially valuable proposition, and could potentially encourage students to better and more continually reference site conditions when designing sites that are relatively nearby, but especially for more distant sites. If a student has immediate access to an immersive visualization of the site, they can quickly proof design concepts against site conditions at any time during the process. Similarly, instructors could utilize the video to better critique and assess student’s designs.



Unwrapped dimensions - 2560 x 1280

1504 x 1504 - Native dimensions

Fig. 2: The native video output of the camera is 1504 × 1504. However, the image quality is noticeably degraded once the video is unwrapped (2560 × 1280), the process of flattening the video, in order to be viewed in a full 360 degrees.

To maximize the value of using 360-degree videos, proposed here is a set of best practices in the capture and subsequent use of the 360-degree video. First, it was clear from this experiment that a higher resolution camera will be beneficial. The 360fly camera captures high definition video, but this is a deceptive specification because, once the video is stretched and wrapped around 360 degrees, the experienced resolution is much lower, approximate 360p quality (Figure 2). In order to have a true HD 360-degree video, the native resolution of the video must be 4k, and preferably 8k. However, YouTube and most VR viewers currently only support 4k, or less, 360-degree videos. A 4k video can be produced utilizing several commercially available systems that utilize synchronized GoPro cameras arrayed in a globe, and it is recommended that such a system be used for the capture of 360 videos. Using such a system can also eliminate the blind spot in the nadir.

In selecting the type of vehicle to mount the camera to, the two most important factors to consider are the nature of the ground plane and the number of vertical obstacles on the site. In most instances a terrestrial drone is preferable, however, accommodation will need to be made in order to deal with sharp grade changes or especially uneven terrain. If numerous obstacles are present on the ground plane, an aerial drone might be utilized provided there are not an unacceptable number of vertical obstacles such as trees, lamp posts, power poles, etc.

In this experiment, however, the camera was positioned at 1.1 meters in order to mitigate for the nadir blind spot. It is recommended that the camera be positioned at 1.5 – 1.8 meters to provide as natural a viewpoint as possible, and it is believed that at this position students will also have an easier time interpreting slopes. In order to mitigate for as much filter bias as possible, it is recommended to have the drone pass over the site multiple times, using different paths each time. This is intended to capture as many potential viewpoints as possible within the video.

It was the opinion of the students in this experiment that a state of declining return would set in for videos longer than 15-20 minutes. Because of this, 360-degree video is optimally used on smaller sites (around 1 acre). For use on larger sites, it would be recommended that the site be partitioned into smaller sections, or that 360-video be captured of only the most important areas of the site as determined by the instructor. This later option should be avoided, if possible, as it reintroduces significant amounts of filter bias, the elimination of which was a primary motivation for the use of 360-degree video.

When viewing the videos, students should be encouraged to view the video first using a VR headset. This is to provide students with as immersive of an experience as possible in viewing the site, and to provide them with a good overview of the structure and feel of the site. Students should then view the video on a computer in order to analyse the site, returning to use the headset in instances where they need to experience a more immersive viewpoint to interpret site conditions. If possible, directional markers should be added to the video to indicate cardinal directions. Doing this will assist students in preparing the site analysis by enabling them to spend less effort interpreting their orientation within the site. Finally, instructors should reinforce students referencing the 360-degree video by utilizing them in critiques.

5 Future Research

This research has demonstrated that the use of 360-degree video for site analysis holds significant promise as both a stand-alone method for geographically distant sites, and as a valuable supplementary resource for students to virtually revisit a site. Future research needs to assess the impact of improved video resolution, to confirm the theory that the level of detail in the analysis will increase commensurate with increased resolution. Future research should also examine the use of 360-degree video to improve teaching methods in distributed design education and virtual design studios.

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