Flying High: A Case Study of the Integration of Drones into a Landscape Architecture Curriculum

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Abstract: The use of unmanned aerial vehicles (UAVs), or drones, is becoming increasingly important to the field of landscape architecture, and universities need to adapt their teaching practices to prepare students to use this technology in practice. This article describes the creation of a Department-wide drone program to train students on the operation of UAVs and the other components that compose an unmanned aerial system (UAS). This program led to impacts in faculty decisions regarding projects, as well as broader curricular changes. While the program has been demonstrated to be both successful and sustainable, several hurdles have had to be addressed in order to achieve this success.

Keywords: Unmanned aerial vehicles, unmanned aerial systems, photogrammetry, curriculum

1 Background

Unmanned aerial vehicles (UAV), colloquially referred to as drones, and all of the ancillary peripherals and software components, collectively referred to as unmanned aerial systems (UAS), are becoming an increasingly important tool for landscape architecture firms. A survey conducted by the ASLA Digital Technology Professional Practice Network found that 55% of firms currently report utilizing drones in some capacity, and an additional 40% of firms intend to adopt drones in their practice, suggesting that drones could quickly become ubiquitous in practice (GEORGE & SUMMERLIN 2019). This follows trends seen in other geographically-focused disciplines (GETZIN et al. 2012, TORRES-SANCHEZ et al. 2014, SIEBERT & TEIZER 2014). With UAS seeing a rapid adoption, it will become important for students to be trained on the use of UAS during their schooling or, at minimum, to be familiar with the processes involved with operating and interfacing with the UAS. However, implementing a UAS in an academic setting can be expensive and fraught with road blocks related to safety, liability, and regulations, and these factors may constitute a deterrent that prevents departments from fully embracing this new technology.

This article presents a case study of the integration of drones into the landscape architecture curriculum of a university in the United States. In this instance, the use of drones has impacted nearly every student and studio course, has resulted in the adoption of this new technology by both students and faculty, has led to the FCC-certifying of several student operators, the adoption of additional software, and an increase in the accuracy and detail of student design work. Additionally, this integration has led to the formation of partnerships with industry to help support the work of students and faculty researchers. The researchers of this study have engaged in this program from the onset and have collected diverse types of archival data in multiple years, which allows for a "thick description" of its process and outcomes.

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2 Literature Review

The last few years have seen a rapid increase in UAS use in both the private hobby sector and commercial uses. This has also been true in landscape architecture, as firms have identified a variety of valuable uses for UAS throughout their workflow. Thus far, UAS have been utilized primarily for remote sensing and aerial photography applications. HAHN (2013) demonstrated the effectiveness of pairing UAVs with LIDAR and photogrammetry to create detailed terrain models. MILLIGAN (2019) further demonstrated the value of UAS for this purpose, additionally exploring the ability of UAVs to easily provide temporal terrain data on sites with fluid conditions. Not only does a UAS allow for mapping terrain, but they can also successfully be deployed to model and map structures on a site or in an urban environment (BARTH 2017). UAVs are commonly used to collect imagery data to supplement the site inventory and analysis process, and are particularly useful for taking photographs in areas, or from perspectives, that are difficult to access, or completely inaccessible (REKITTKE et al. 2013). KULLMAN (2017) demonstrated the improved effectiveness of UAS in capturing aerial imagery compared to traditional methods of satellite or plane-based cameras. UAS also enable designers to capture video of their sites, which help remind and move our understanding of site condition beyond static photographs, and can prove a powerful communication tool (TOOMEY 2015). They have also been used to accurately measure and document the use of sites (PARK 2019).

3 Context

The drone program at the University was initially established as a student-led initiative in 2014 with a kit-built quadcopter UAV. This student initiative quickly became sanctioned by the landscape architecture department which, at a time when government regulations regarding UAVs were poorly defined and in flux, created concerns with the University's legal department. As a result of these concerns, a formalized program was created within the landscape architecture department, overseen by a faculty member, to ensure the legal and safe operation of the UAVs by students and faculty. To assist the faculty member, a student supervisor was also selected to help manage the equipment and coordinate amongst the operators.

Initially, use was confined to the initial student who built the UAV, and only he and his classmates benefited from the terrain data and aerial imagery that was captured. However, as faculty became aware of the available benefits, the single student became overwhelmed with trying to fulfill requests to fly the UAV over project sites. To deal with this situation, the faculty member managing the program instituted a training program to increase the number of pilots that would be allowed to operate a UAV. This increased the number of trained students from a single operator to five operators within the first year. Additionally, the department purchased four additional UAVs to ensure the availability of a UAV to the operators.

With the subsequent establishment of formal regulations, it was decided that student operators should be formally certified by the FAA to operate a UAV owned by the department. Although students are legally permitted to operate a UAV as part of their education without a certification, requiring the certification strengthened the program's legal and liability position, enabled students to more safely operate the drones (especially in urban conditions with controlled airspace), and improved their subsequent hirability by ensuring they would be able to commercially operate a UAV after graduation. To improve students' preparation for certification, the landscape architecture department coordinated with the University's aviation program to offer a class on drone operations that would be available for landscape architecture students to take. As a result of this partnership, on average 4-6 students have become certified operators each semester. Multiple students who have graduated were hired by firms at least partially due to their ability to commercially use UAS for their new employer.

4 Processes

There are several applications of the UAS in the Department, the processes for the most frequent of which are described in detail here. The Department currently operates three DJI Mavic UAVs and one DJI Inspire UAV; photogrammetry processing is done with Pix4D. Once a faculty member has identified a project for which they wish to have a UAV flight, they contact the student supervisor and meet to discuss the site. This preliminary discussion consists of reviewing the site on a map to identify the needed data, the data collection boundaries, nearby obstacles and no-fly zones, and to establish a timeline for completion. While the Department funds the UAS, individual faculty are required to pay for the student operators' time. This has subsequently led to faculty including UAS time on most contracts with clients.

Once details have been gathered, the supervisor will assign the flight to one of the student operators. Prior to departure for the site, physical checks are done on the equipment to ensure that the drone is in good condition, that adequate batteries and back-up batteries are charged, that all connection cables are accounted for, and that weather conditions will be suitable for flying. Additionally, two students are required to travel for each flight, one as the operator and the other as the spotter to watch out for potential obstacles or hazards.

On site, student operators use an iPad Mini to set the flightpath using the Pix4d Capture app, which enables improved interfacing with the Pix4d desktop app. The most common use is to gather accurate aerial photography and topography data to be used throughout the design process. For these types of projects, flights occur between 100'-150' of altitude with 80% image overlap and the camera facing directly towards the nadir. With ideal wind conditions, a drone can cover approximately 30-40 acres of terrain with these flight settings before the battery will need to be changed (approximately 20 minutes of flight time). Using the built-in cameras on the drones, even at higher altitudes, produces much better images than are available via commercial satellite imagery (see figure 1). At times the Department has used the larger Sirius Mavinci and Falcon 8 UAVs, both of which are able to fly near the 400' regulatory elevation while still capturing high quality imagery. However, both of these are considerably more expensive, have shorter flight times, more complex systems, and it is also more difficult to obtain replacement pieces for these UAVs in a timely manner. Because of these factors, the Department has chosen to exclusively use the DJI drones. This has the added benefit of making it easier and more affordable to maintain an inventory of spare parts.

Following the drone flight, the imagery is processed using Pix4d photogrammetry software on a custom-built photogrammetry workstation with 16 Intel core i9 processors, 128 GB RAM, and dual Nvidia GeForce GTX 1080 Ti graphics cards. This process produces a point cloud, high-resolution photo mosaic image file, a 3d mesh file, and three-dimensional contour data (see Figure 1). When ground control points are used on site, the resulting contour data is accurate to within 2 cm. Typically ground control points are not used, but the contour data is still accurate to within <10 cm, although the density of vegetation cover may impact this accuracy. It quickly became apparent that hard drive space would be a recurring issue and, to manage this, the raw imagery, the generated photomosaic, and the 3d mesh file, are saved on external hard drives. The Pix4d project file and other outputs are saved on the computer hard drive, with the empty image folders preserved in the file structure so that the raw images could be reinserted for processing at a future time.

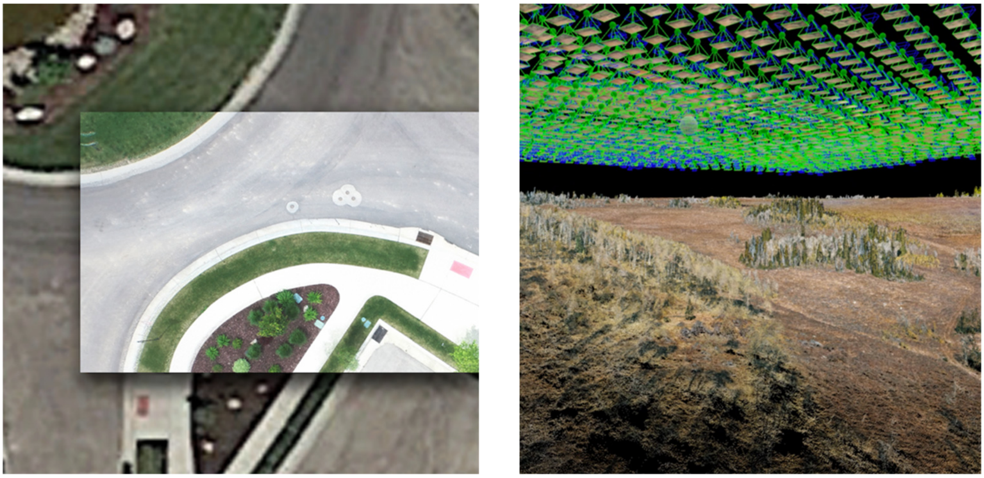

Fig. 1: On the left, a comparison of satellite (background) and UAV (foreground) captured imagery. On the right, the point cloud of a site showing the grid of photos taken from the UAV above it.

The second most common use of UAS is to collect low-altitude video footage for use in documenting and analyzing site conditions, and for use in presentation material in the final project outputs. The ability to quickly produce stable videos from a variety of altitudes, and over terrain that may otherwise be inaccessible, has helped students develop a deeper understanding of the site through being able to clearly document movements, different perspectives, and potential paths. These types of flights are normally flown using manual controls and are reserved for the most experienced student operators, as they often occur at much lower altitudes in urban areas with many more obstacles.

The UAS are also utilized to gather data for research, often times using different sensor packages, primarily infrared and 360-degree cameras (because the Department operates smaller UAVs, capturing data using a mounted LIDAR system is infeasible). Several undergraduate research projects and graduate thesis have been tied to the use of UAS in landscape architecture. And faculty are now researching the use of UAS for a variety of applications beyond traditional mapping and media collection, such as for at-a-distance site analysis and site-use assessments and post-occupancy evaluation (POE), plant communities, and historic conditions. The ability of the UAV to provide an elevated view in a largely unobtrusive manner has been particularly valuable in collecting site-level data.

5 Interfacing with the Public

The increasing prevalence of commercial drones has led to a corresponding increase in concern by the public regarding privacy and safety in countries across the globe (BAJDE et al. 2017, RICE et al. 2018, ZWICKLE et al. 2019). This increased sensitivity to the use of UAS, especially in urban areas, has been an important issue to deal with. As part of obtaining their operator's license, students are made aware of regulatory requirements regarding where it is safe and legally permissible to operate a drone, and they are expected to work within those rules. However, students are also expected to take a "good neighbor" approach when on site.

When contact is possible, students try to notify surrounding property owners that they will be operating a drone, identifying themselves as university students and describing the purpose of the flight. When operating in public spaces (such as parks), city or park managers are notified, and students typically wear clothing with university logos to help identify the purpose of the flights. For large projects which cover expansive portions of a community, notification is given to the municipality. Often times this may not be necessary, as it is normally city officials who have contacted the Department about having students work on the design project.

During the life of the drone program, there has not been a reported incident where a student operator has been accosted by a property owner or bystander over the operation of the UAV. It is very common for people to approach the students out of curiosity in order to learn more about UAS. While these interactions have been friendly, they have, on occasion, led to several near-miss incidences where the operator and spotter have been distracted by conversation.

6 Impacts on Pedagogy

While student interest and adoption of UAS was critical to the initial creation of the drone program, it was faculty buy-in that ultimately led to UAS becoming entrenched in the curriculum. UAS are now integrated both vertically and horizontally throughout the curriculum, being used at every grade level and in every studio and the standard use of UAS-gathered site data in the Department for projects has resulted in several impacts on course pedagogies. Initially, faculty were primarily interested in generating contours from photogrammetry processes. Because of the difficulty and time required to create accurate contour data using traditional surveying methods, only faculty in grading and construction courses typically asked students to produce accurate highly grading plans for their designs. However, the UAS-generated data dramatically improved the accuracy of contour data that students could work with, which in turn enabled all faculty to provide more detailed instruction, critique, and feedback related to site conditions on projects and faculty in most studio courses now frequently expect grading plans. As a result, students have become increasingly competent at reading and working with contour data.

Similarly, the improved resolution of aerial imagery available on projects has made students more aware of site conditions and led to further improvements to design decisions through providing access to more accurate and precise imagery of site conditions. The use of UAS also led to the regular integration of video into design projects and final presentations. Having the ability to experience site conditions and integrate design proposals into aerial video has allowed students to explore a new medium for expressing their ideas and communicating them to clients. While some faculty were initially skeptical of the value of UAS, focusing on the outputs, as opposed to the technology itself, quickly led to universal adoption of drone use by faculty in their studios.

The drone program has had several substantial impacts to the way students design. The improved contour data has resulted in improved understanding of grading procedures and forced students to be more precise with their grading decisions. This has translated into more accurate representations of final site conditions, as students are now able to integrate highly accurate terrain data into their visualizations. Imagery collected from the drones has also altered the way that students view the site by providing views from a variety of different perspectives and allowing students to revisit the conditions of the site more accurately. The use of drones has also spurred interest in and the adoption of other emerging technologies that can interface with drones, such as 360-degree video, virtual reality, photogrammetry software, and 3d-printing.

This improved data has also opened the door to collaboration with other disciplines and directly led to several research projects and industry partnerships. The Department partnered with Intel to research the use of UAS and virtual reality for understanding and designing in the landscape. In another instance, after collecting contour data, a property owner connected a faculty member with an engineer and surveyor who were conducting simultaneous work on the project to enquire about sharing data. This led to conversations and additional data that contributed towards the students' work on the project. Several similar incidences have occurred with city staff who were interested in having access to the drone data.

Fig. 2: Benefits of UAS data includes enabling students to design with more accurate contour data (left). It has also resulted in partnerships with industry, including collaborating with Intel's drone team (right).

While the increased data has provided several benefits to student workflows, an important impact has been that students increasingly rely on the UAS data, often at the expense of good on-site inventory and analysis. It would seem likely that the UAS use will significantly alter the approach to site inventory and analysis, perhaps pushing designers to more frequently conduct site analysis at a distance. Furthermore, faculty appear to be more willing to work on projects farther afield where they can get good UAS data, but may not be able to actually take the class of students to the site. While the increased availability of remote sensing data sources has made it possible for more and more of the site inventory and analysis process to be done at a distance, there is an increasing danger that students are relying too heavily upon these tools and not spending the time experiencing the true physical characteristics of a site. Students are increasingly following Jane Jacobs' suggestions to "look closely at real cities," but are not following her further appeal to "listen, linger, and think about what [they] see." (JACOBS 1965).

7 Issues and Limitations

While the drone program has been largely successful, there have been multiple challenges. The most prominent challenge was navigating the nebulous legal environment of drone operations. This created concerns at both an individual level with operator liability, and at a university level. Many liability concerns revolve around safety, both of for the operator and the public, and careless UAV operation can quickly lead to damage of equipment and infrastructure or injury. While improved guidelines from the FCC have lessened liability concerns, legal concerns can continue to be an issue on some sites because of varying municipal laws and proximity to controlled or restricted airspace. Privacy concerns are also prevalent, and the operation of a UAV can provoke negative reactions from residents and property owners.

There are also limitations to the type of data gathered through a UAS, especially from obstructions such as tree canopies. Photogrammetry software is impeded by dense canopies, preventing the creation of accurate contour data, and LIDAR-equipped UAVs are considerably more expensive. Similar impediments exist with infrared data collection.

As discussed earlier, another challenge has been managing the inventory of drones that the department owns. This includes issues related to checking out the drones to individual operators, the maintenance and repair of drones, and updating software and firmware. These management issues are inherent in any university program, as experienced students graduate and novice students come, which may highlight a need for recruiting a longer-term staff to oversee operations of the program.

8 Conclusion

The creation of the drone program has significantly improved the educational experience of students. Beyond the originally expected improvements to base data that students have available to them, it has led to innovation and the adoption of other technologies, improved the job prospects of graduating students, and created opportunities for research and collaboration. Although management of the program can be time consuming and has required navigating a complex legal and regulatory environment, the realized benefits will ensure that the department continues to utilize, invest in, and train students in the use of drones.

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