Higher Education Studies; Vol. 13, No. 2; 2023
ISSN 1925-4741 E-ISSN 1925-475X
Published by Canadian Center of Science and Education

Assessing Drone Mapping Capabilities and Increased Cognitive Retention Using Interactive Hands-On Natural Resource Instruction

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Received: March 1, 2022 Accepted: March 25, 2023 Online Published: March 29, 2023

doi:10.5539/hes.v13n2p28 URL: https://doi.org/10.5539/hes.v13n2p28

Abstract

The use of Unmanned Aerial Systems (UAS), also known as drones, is increasing in geospatial science curricula within the United States. Four geospatial science faculty members within the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University (SFASU), Texas, focus on applying imagery obtained from drones to map, monitor, and quantify natural resources. To produce society-ready foresters, natural resource managers, and environmental scientists, the geospatial science faculty employ an intensive one-on-one hands-on interactive approach in training future resource management professionals in how to effectively apply drone technology within natural resource endeavors. In particular, recent instruction has focused on training students how to evaluate the amount of overlap and sidelap percentages required within a drone flight to create the optimum orthophoto mosaic. Results indicate that the one-on-one interactive methodology employed by faculty at SFASU produce highly qualified drone pilots capable of providing the drone community with new insights on how to produce accurate orthophoto mosaics in a timely and efficient manner.

Keywords: student, curricula, orthophoto mosaic, overlap, drone

1. Introduction

1.1 Analog Remote Sensing versus Unmanned Aerial Systems (UAS)

Obtaining imagery of the Earth’s surface from a distance can be dated to the first aerial photograph obtained from a hot air balloon in 1858 (Paine & Keiser 2003). With the advent of airplanes in the early 1900’s, the ability to acquire photographs of the Earth from above on a routine and repetitive basis became more commonplace. Photographs obtained via airplanes, typically acquired via a nadir perspective which simply means the camera is pointing downward or at a right angle to the surface of the Earth, provide the viewer with a large view of the Earth’s surface in either a monocular or stereoscopic perspective.

A monocular view would entail a single aerial photograph that could be interpreted as a small map of the area enclosed within a single aerial photograph. A stereoscopic perspective view would entail a series of aerial photographs acquired along the plane’s flight path with each successive photograph overlapping the previous photograph by a standard overlap of 60 percent. A sequential pair of aerial photographs is called a stereoscopic pair, and with the aid of a stereoscopic viewing instrument, a viewer could view the overlapping sections in 3D allowing for the quantitative assessment of vertical features and elevation within the aerial photographs. Along adjacent airplane parallel flight paths a standard sidelap of 30 percent is also obtained to ensure that if the plane drifts the project area will be completely covered within the aerial photographs (Paine & Keiser 2003).

More recently, and with the advent of digital cameras, aerial imagery has been recorded in digital format as opposed to the analog or photographic format typical since the early 1900’s. The advantage of digital imagery is that these data can be manipulated mathematically to derive information not previously available with traditional aerial photographs.

The use of Unmanned Aerial Systems (UAS), also known as drones, is increasing in geospatial science curricula across the United States. The reason being is that the use of data of the Earth’s surface acquired from the sky no longer has to rely on an airplane which can be time consuming and financially expensive. Drones, which can be launched locally for site specific information, can be controlled locally and flown to acquire digital aerial imagery under control of the local user. To maintain data collection continuity, drone acquired imagery typically follows the data methodology that originated with the advent of aerial photography and follows the overlap and sidelap percentages that have been used historically but with more variable percent options (Figure 1).

At a very basic level traditional analog remote sensing can be compared to drone remote sensing since they both acquire imagery of the earth's surface from a distance. However, there are subtle yet important differences between the two systems (Table 1). Aerial photographs obtained via a plane platform are considered analog data which consists of a physical photograph that can't be manipulated. This data acquisition method requires a human to visually interpret each photograph which can be a time-consuming endeavor when it entails numerous aerial photographs. Drone imagery, on the other hand, is considered digital data which consists of a digital image that is able to be manipulated digitally with a computer. As a result, the processing of drone imagery is more effective in terms of time and cost when compared to aerial photographs.

Within the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University, geospatial science faculty are involved with training students in drone technology to enhance their educational experience (Unger, Kulhavy, Hung, Zhang & Stephens Williams 2019). To achieve that goal, the geospatial science faculty train and involve students in drone related research projects to not only validate current drone research methodology but to educate students, particularly graduate students, how to also pursue original drone research endeavors; all within an interactive one-on-one teaching methodology (Figure 2) (Kulhavy, Hung, Unger, Viegut & Zhang 2021).

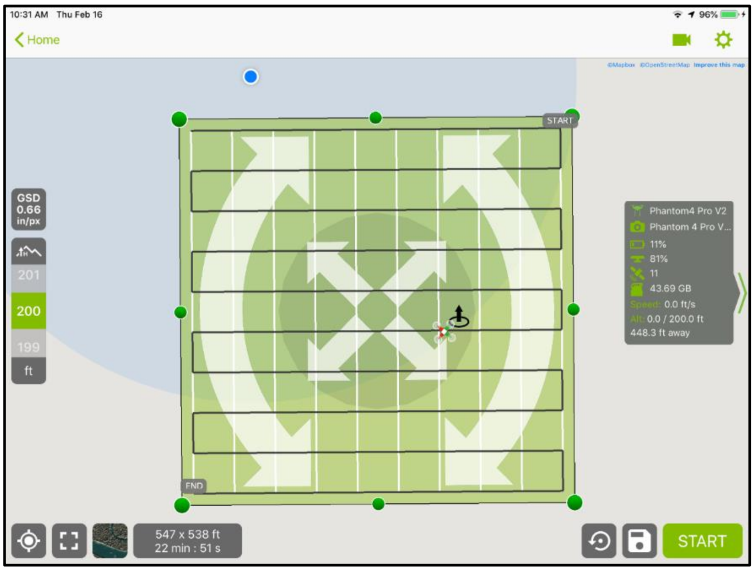

Figure 1. Example of a drone flight path depicting 80 percent overlap and 80 percent sidelap flight lines for orthophoto mosaic creation

Table 1. Plane versus drone data collection characteristics

Data Collection	Data Type	Imagery	Interpretation	Assessment	Assessment Time
Plane	Analog	Aerial Photograph	Human	Visual	Slow
Drone	Digital	Digital Image	Computer	Digital	Fast

Figure 2. Faculty member providing graduate student interactive hands-on field instruction

Under the general umbrella of drone related research and educational projects, the geospatial science faculty ensure that each student’s education and research project use the most current technology to create a viable product (Bullard et al. 2014; Zhang et al. 2023). Often drones are used to complete projects and produce products across the natural resources and geospatial science curriculum (Unger, Kulhavy, Hung, Zhang & Stephens Williams 2019). Students are additionally trained in the safe use of a drone by the four geospatial science faculty members including safe operation, flying the drone for individual images, video and orthophoto missions using a four-step training process of drone assembly, completing a controlled flight, capturing imagery and videos, and synthesizing drone information to quantify and qualify natural resource missions (Unger, Kulhavy, Busch-Petersen & Hung 2016; Unger, Kulhavy, Hung, Zhang & Stephens Williams 2019).

1.2 Orthophoto Mosaic

One of the most basic uses of a drone is to generate an orthophoto mosaic of a study area. This is basically a highly accurate georeferenced image in digital form of a study area. By obtaining imagery along predetermined parallel flight paths, and along perpendicular predetermined parallel flight paths in a grid pattern as visualized in Figure 1, the subsequent digital images can be stitched together with highly specialized computer software to produce a continuous image of the study area which is called an orthophoto mosaic. Through geographic positioning, edge matching, and photogrammetry, this orthorectify process generates a highly accurate and useful digital image that can be used as a base map in many geospatial science projects (Hung, Unger, Kulhavy & Zhang 2019).

A DJI Phantom 4 Advanced version 2 drone was integrated into undergraduate forestry instruction to enhance learning of remotely-sensed spatial information (Unger, Hung, Zhang & Kulhavy 2018). Kulhavy, Unger, Hung & Zhang (2016) found no difference in visual assessment and drone assessment of urban tree hazard rating. Twice as many mistletoe plants were counted using the DJI Phantom 4 Pro drone compared to ground surveys (Kulhavy et al. 2019). Drones were integrated into service-learning for a capstone forestry course (Kulhavy et al. 2017). Drone use is increasing in teaching, research and service across the curriculum and they are an essential tool for natural-resource management decision-making (Unger, Kulhavy, Hung, Zhang & Stephens Williams 2019). For drones, Muhammad and Tahar (2021) found an overlap of 80 percent and a sidelap of 50 percent at 60 m has the lowest RMSE compared across overlap and sidelap.

1.3 Interactive One-on-One Hands-On Natural Resource Education

In a recent student research project at SFASU, a graduate student and the four geospatial science faculty members evaluated orthophoto mosaic creation with different overlap and sidelap percentage settings in multiple flight missions. The goal was to evaluate the accuracy and completeness of drone derived orthophoto mosaics under varying percentages of overlap and sidelap. Percentages evaluated included: 50 percent overlap/20 percent sidelap, 60 percent overlap/40 percent sidelap, 70 percent overlap/60 percent sidelap, and 80 percent overlap/80 percent sidelap. Research project objective evaluated the optimum percent of overlap and sidelap that produced the most visually effective orthophoto mosaic in terms of time and efficiency, while simultaneously evaluating the effectiveness of SFASU’s one-on-one interactive teaching methodology.

2. Methods

Using a DJI Phantom 4 Pro version 2 drone, a graduate student under the direct supervision of four geospatial science faculty flew four drone missions over and encompassing the Arthur Temple College of Forestry and Agriculture on the campus of SFASU during the Fall 2022 semester. Flying height for all four projects was 200 feet above ground level covering approximately 13 acres of ground area. Each flight was flown by the graduate student who interactively designed each flight in the field using the Pix4Dcapture application on an iPad linked to the DJI Phantom 4 Pro version 2 controller. The specific overlap and sidelap percentages for each flight were; flight 1 at 50 percent overlap/20 percent sidelap; flight 2 at 60 percent overlap/40 percent sidelap; flight 3 at 70 percent overlap/60 percent sidelap; and, flight 4 at 80 percent overlap/80 percent sidelap (Figure 3). The dots along each flight path identified in Figure 3 represent the center location of each acquired image.

Upon the completion of all four drone flights, the graduate student was instructed by the geospatial science faculty how to download the imagery off the DJI Phantom 4 Pro version 2 drone onto the servers in the Geographic Information Systems (GIS) laboratories housed within the Arthur Temple College of Forestry and Agriculture. Once downloaded, the graduate student was trained initially how to create an orthophoto mosaic using Drone2Map software which is an ESRI software product specifically designed to mosaic individually georeferenced images into a composite mosaic. Upon completion of the mosaic software training, the graduate student under the direct supervision of geospatial science faculty created four orthophoto mosaics representing the four combinations of overlap and sidelap percentages evaluated in the study (Figure 4).

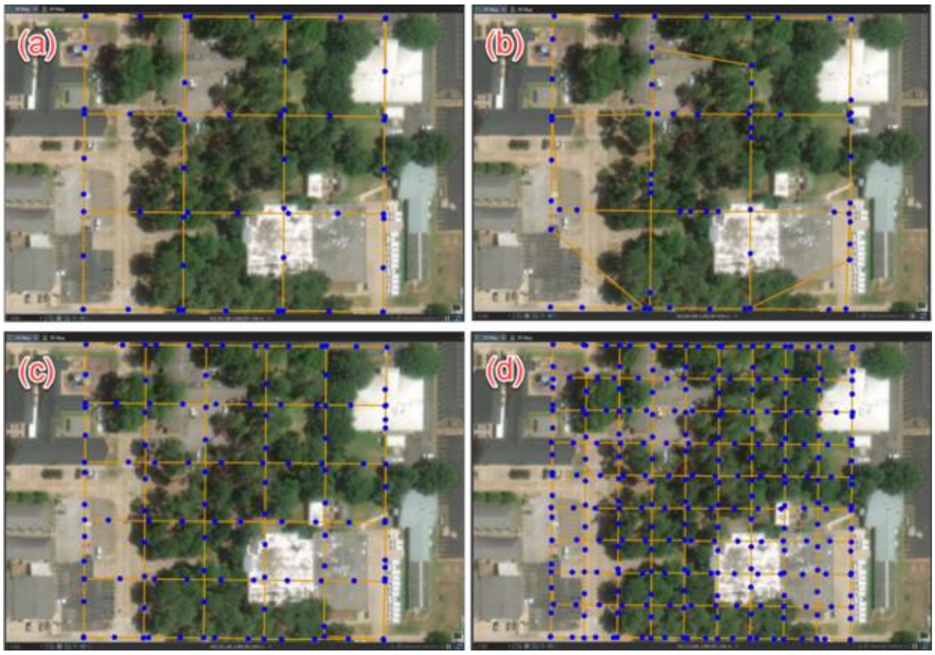

Figure 3. Drone flight path configurations for overlap percentages of 50 percent (a), 60 percent (b), 70 percent (c), and 80 percent (d)

After creating all four orthophoto mosaics, the graduate student and faculty visually inspected each orthophoto mosaic in succession to determine the effectiveness of each overlap and sidelap percentage setting in creating a composite mosaic encompassing the project area (Figure 5). As previously observed in Figure 4, it was visually apparent that the completeness of each orthophoto mosaic varied depending on the overlap and sidelap percentages utilized per drone flight. In particular, it was obvious that the completeness of a created drone orthophoto mosaic was inversely proportional to the overlap and sidelap percentages. The greater the overlap and sidelap percentages the higher the orthophoto mosaic completeness. When creating orthophoto mosaics the Drone2Map relies on tie points with each image to match to each other to create the mosaic; when ties points become minimal per matching images, as is the case with minimal overlap and sidelap, the result has voided areas in the product.

In order to calculate the percentage of completeness per drone flight, the graduate student was trained how to convert each orthophoto mosaic product to a map of completeness using the remote sensing software package ERDAS Imagine. Each orthophoto mosaic was classified into a map depicting two specific areas; an area of coverage labelled completeness and an area of no coverage or no completeness. These areas of completeness and no completeness can be readily identified in Figure 6 represented by the color green and white respectfully. Furthermore, an image area retained ratio was calculated by having the completeness area divided by the total area of the orthophoto mosaic for each drone flight to quantify the area of completeness and no completeness per drone flight.

After the areas of completeness were identified, the graduate student and geospatial science faculty compiled a list of drone derived orthophoto mosaic flight data statistics per overlap and sidelap percentage setting (Table 2). Of particular importance was the number of photos required to produce each orthophoto mosaic, time required per flight, orthophoto mosaic coverage area per flight, and the percentage of area retained in the final orthophoto mosaic product.

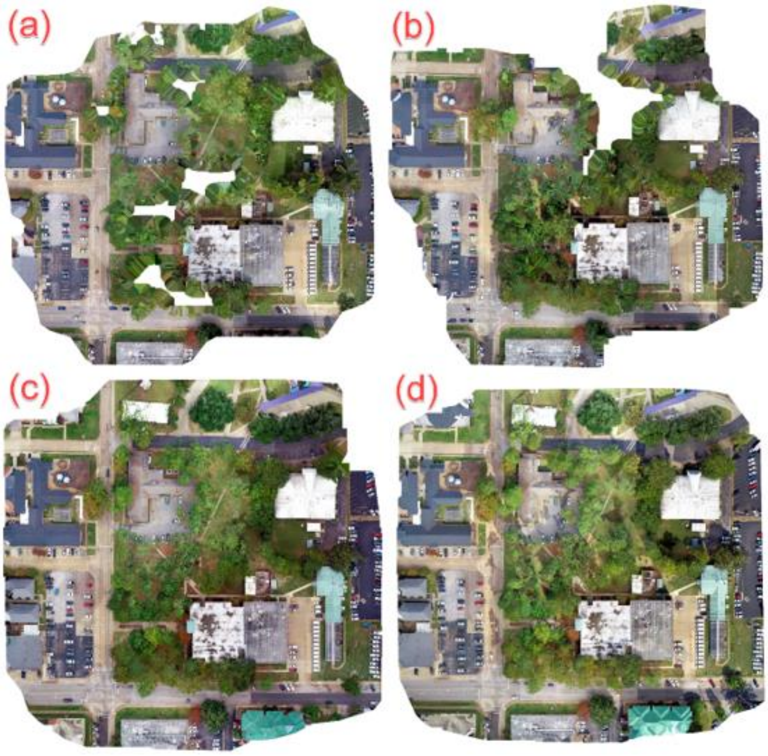

Figure 4. Drone derived orthophoto mosaics for overlap percentages of 50 percent (a), 60 percent (b), 70 percent (c), and 80 percent (d)

Figure 5. Faculty member providing graduate student interactive hands-on software instruction post field data collection

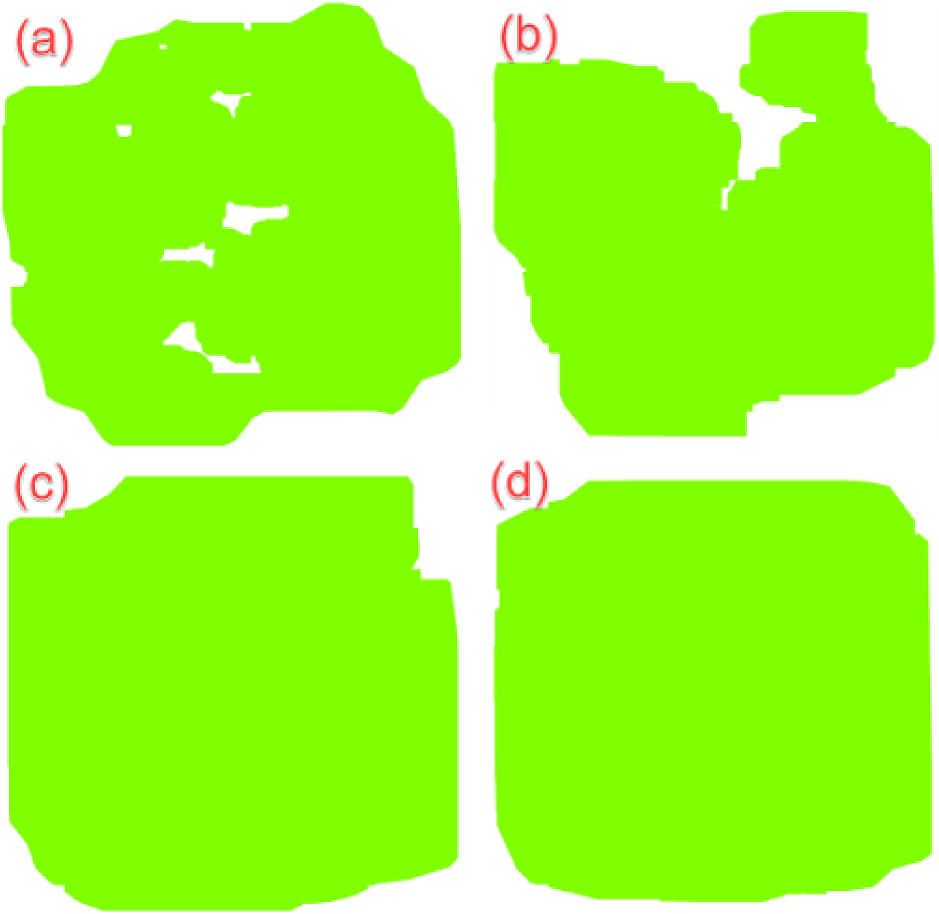

Figure 6. Software derived orthophoto mosaic coverage area maps of completeness for overlap percentages of 50 percent (a), 60 percent (b), 70 percent (c), and 80 percent (d)

3. Results

Results indicated that as the percentage of overlap and sidelap increased from flight 1 (overlap 50/sidelap 20) to flight 4 (overlap 80/sidelap 80), the number of photos acquired to create each orthophoto mosaic ranged from 55 to 279 individual photos, an increase of 5.07 times more photos. Additionally, the time required to complete each fight mission from flight 1 to flight 4 ranged from 383 seconds to 1374 seconds or an increase of 3.58 times more time required to complete flight 4.

Of particular concern was that during the lower overlap and sidelap percentage flights, the areas of completeness were lower in overall total area coverage meaning that the lower overlap and sidelap percentage settings per flight were not sufficient in providing the end user a complete orthophoto mosaic.

However, the last column in Table 2 listing the percent of image retained remained relatively constant when the overlap and sidelap percentage setting were 70 percent overlap/60 percent sidelap or higher. The results imply that an overlap percentage of either 70 or 80, combined with a sidelap percentage of either 60 or 80, would be sufficient in providing a complete orthophoto mosaic.

Table 2. Drone derived orthophoto mosaic flight data statistics per overlap and sidelap percentages

Overlap (%)	Sidelap (%)	Number of Photos	Flight Time	Image Area (Acres)	Background (Acres)	Image Retained (Percent)
80	80	279	22 minutes; 54 seconds	13.62	0.83	94.3
70	60	119	11 minutes; 18 seconds	13.31	1.14	92.1
60	40	63	7 minutes; 2 seconds	10.86	3.59	75.2
50	20	55	6 minutes; 23 seconds	11.16	3.29	77.2

The graduate student and the geospatial science faculty confirmed the data conclusion by visually comparing each drone derived orthophoto mosaic to validate that the 80 percent overlap/80 percent sidelap did indeed produce a visually appealing, more complete, and more accurate orthophoto mosaic (Figure 7).

4. Conclusions

The results from this interactive one-on-one faculty-student research project indicate that the hands-on approach utilized by the geospatial science faculty in the Arthur Temple College of Forestry and Agriculture is an effective methodology in producing students well-versed in being able to use drone technology to effectively map, monitor, and quantify natural resources. This skill set is affirmed in the training of students to become effective natural resource managers to solve complex ecological and societal problems using analytical skills (Bullard et al. 2014) reaffirming the use of drones as a tool to in natural resource education and as a communication medium in society (Kulhavy et al. 2022).

Figure 7. Drone derived orthophoto mosaic for 80 percent overlap and 80 percent sidelap

In particular, a graduate student and faculty members working interactively together learned that when compiling a drone flight to create an orthophoto mosaic that an overlap percentage equal to or greater than 70 percent combined with a sidelap percentage equal to or greater than 60 percent would create the most complete orthophoto mosaic. Percent overlap and sidelap values less than these parameters were shown to be unsatisfactory in creating a complete ortho photomosaic.

This project focused on training students how to evaluate the amount of overlap and sidelap percentages required within a drone flight path to create the optimum orthophoto mosaic. By observing a graduate student post initial training, the geospatial science faculty were able to observe a graduate student first hand applying their newly obtained knowledge within a real-world project from the initial design stage to the analysis of project results. Results of this study compare favorably with prior overlap/sidelap studies (Muhammad and Tahar 2021).

These results not only validate the utility of drones within a natural resource curriculum but confirm the effectiveness of the geospatial science faculty hands-on instruction methodology in increasing a students' skill level and confidence to complete drone related projects independently in the future.

Acknowledgements

This work was supported by a McIntire-Stennis grant administered by the Arthur Temple College of Forestry and Agriculture and a Center for Applied Research and Rural Innovation grant, Stephen F. Austin State University, Nacogdoches, Texas, USA.

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