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Advancements in Archaeology Through Remote Sensing

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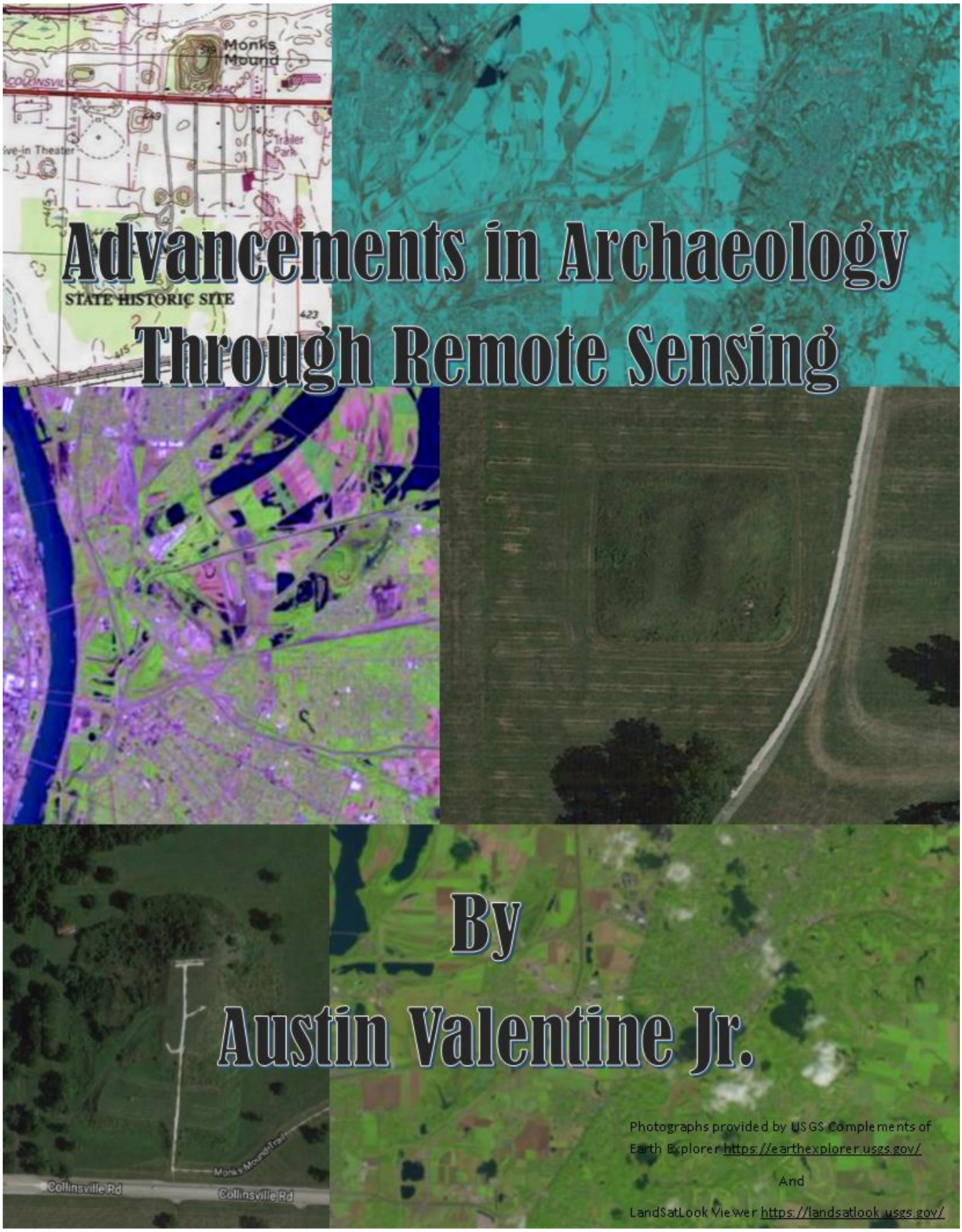


Advancements in Archaeology Through Remote Sensing

By

Austin Valentine Jr.

Photographs provided by USGS Complements of Earth Explorer https://earthexplorer.usgs.gov/

And

LandSatLook Viewer https://landsatlook.usgs.gov/

Abstract

One aspect of remote sensing applied to archaeology is through the utilization of aerial photography. Some of the first records of aerial photographs being applied to the discipline of archaeology date back to the late 1920's. One such example was a series of photographs taken by the famous pilot Col. Charles Lindberg. Col. Lindberg, who was actually fascinated with the field of archaeology, made a series of flights taking photographs of the Chaco Canyon in New Mexico as well as Maya ruins in both Mexico and Guatemala (Thomas and Kelly 2006).

Since, archaeology has become a science that can be conducted from both aloft as well as from the ground. This is conducted through the utilization and integration of drone photography and 3D modeling. With such tools archaeologist now have the ability to take a more noninvasive, broad-spectrum, and site preservation approach to historical investigation and research.

This article examines some of these new techniques and gives examples of their relevance applied to the discipline and ethics of archaeology. Through the utilization of real-life examples, the reader will gain insight into the art, science, and relevance of archaeology's future from an aerial standpoint.

Introduction

With past modernization and present-day industrialization comes exponential population growth in many areas, not just in the United States but around the world as well. As these towns and cities grow so does their social, economic, and environmental footprints; a growth which yields vast areas of uncontrollable development, construction, and mountains of garbage and refuse. With such growth also comes the exploitation of both renewable and nonrenewable resources (American Society of Photogrammetry 1975).

However, one nonrenewable resource commonly overlooked by expansion are those areas of unknown historical importance. One example is the Mississippian Indian Mound sites like those located in Cahokia, Illinois; which have been threatened by highway construction and urban development in past years (Pauketat and Bernard 2004).

Despite rapid industrialization of cities and towns, there are also numerous rural areas of undetermined historical value across the country being unknowingly threatened by agricultural expansion. With such rapid growth comes the need for remote sensing to understand this impact from an aerial perspective and archaeologists to interpret the collected information.

Such needs substantiate remarks made by Dr. Luis Jaime Castillo, Professor of Archaeology at the Pontificia Universidad Católica del Perú. He once stated that archaeologists "*are the detectives of the past, and we have to figure out what happened; that is what is fascinating about archaeology* (Castillo and Parcak 2017)." Castillo also noted it has been a dream of past archaeologists to possess the ability to look at historically significant sites from above (Castillo and Parcak 2017).

Castillo's statements aid in the justification in the ability to view the world from an aerial perspective. Such capability allows researchers to conduct noninvasive surveys of potential sites

of historical interest. These techniques also allow researchers conducting excavations to monitor their site for comparison to what archaeologist are seeing on the ground during their dig. Thus, providing researchers another tool to aid in the preservation of future sites from the encroachment of industrialization and population growth (Castillo and Parcak 2017).

This aerial ideology is not just a recent concept, it actually dates back to mid-19th century Paris, France during 1858 with photographer and balloonist Gaspard-Félix Tournachon. In 1855 Tournachon patented his idea of taking aerial photographs, feeling such images would have a valid use in both mapmaking and surveying applications. Thus, in 1858 Tournachon conducted the first successful flight over Paris taking a photograph of the village of Petit-Becetre at the height of 80 meters (PAPA 2018).

Tournachon's success blazed a trail for the first aerial photographs, but it's utilization in the field of archaeology was not immediate. As camera technology and film development advanced, archaeologists utilized Tournachon's ideas by attaching cameras to unmanned balloons and kites in an effort to gain a new perspective of their sites. Devices such as these eventually gained the name Unmanned Aerial Vehicles (UAV's), which allowed researchers the ability to safely identify new locations that may present future interest to both archaeologist and anthropologist alike (Thomas and Kelly 2006).

The application of aerial photography in the field of archaeology took its second major advancement after the first successful airplane flight in 1903. But, it wasn't until the late 1920's when aerial photography came into the national spotlight. This technological advancement started by accident during a series of 1928-1929 winter flights conducted by the famous pilot Colonel Charles Lindbergh.

Col. Lindberg was searching for possible air routes for the Pan-American Airways when he passed over the jungles of the Yucatan Peninsula spotting concentrations of Mayan ruins. During one of his journeys he took photographs of the site, which are the earliest known archaeological photographs of this area (Thomas and Kelly 2006).

Shortly after Col. Lindberg's airplane journey across the Yucatan, the United States began to broaden its aerial horizons by concentrating scientific efforts on rocketry. As technology advanced, so did the desire to take aerial photographs from greater altitudes. It wasn't until 1946 under the direction of NASA scientist John T. Mengel did the art of aerial photography reach an extra-terrestrial level. Mengel utilized captured German V-2 rockets to take aerial photographs from over 100 miles above the earth's surface (NASA 2009).

By the fall of 1957 aerial photography inadvertently took another evolutionary leap. This occurred on October 4th when the Soviet Union launched the first ever communications satellite in orbit called Sputnik I. Thus, starting a contest between nations known as the great space race (NASA 2007).

Seeing the possibility of conducting high-altitude photography from satellites, researchers began to focus on the idea of creating satellites capable of imaging. However, initial justification for such applications were based solely on military perspectives and not on educational objectives.

Since the days of Sputnik, governments and private agencies from around the world have launched numerous satellites into space possessing both photographic and communications capabilities. Such satellites now have the ability to not only take visible images but produce images from other areas of the electromagnetic spectrum, giving researchers a broad multi-

spectral range of ability when it comes to analysis and mapping of the earth's surface. Many of these images are now provided free of charge to researchers as well as the general public. Thus, making the art of image analysis open to both professionals and hobbyists.

With unlimited access to such images, researchers now have the ability to examine large areas surrounding historically significant sites without fear of exceeding budgets. Dr. Luis Jaime Castillo sums this ability in stating; "b*y going into space we can look at not one square mile, but many square miles. Then you can focus on specific items that you think are important* (Castillo and Parcak 2017)."

Despite the rapid expansion of remote sensing into the heavens, the art and science of aerial imaging still possesses a vast number of lower-altitude applications. If anything, these lower-altitude applications have become just as essential as satellite imaging. Such tools have exhibited relevance in commercial fields such as agriculture, construction, and real-estate.

This vast need has shifted researcher's focus from expensive manned remote sensing techniques such as aerial photography to a more economical unmanned approach. Thus, giving birth to small unmanned aerial vehicles, known as Dynamic Remotely Operated Navigation Equipment (DRONE's), which are capable of producing quality photographs and video (Abbreviations 2018).

These compact radio-controlled devices, in the past three years, have transformed the art of remote sensing in numerous ways. Now both professionals and hobbyist alike can possess the ability to conduct economical aerial photographic operations for both private and commercial applications. This coupled with enhanced computerized imaging software and coupled with satellite imaging have modernized the art of remote sensing.

Through examples of both satellite and drone image analysis, we will explore the topics of aerial photography as well as conducting archaeology from aloft. Thus, exploring both the capabilities and deficits in such application while illustrating the effectiveness of such technology. By looking at both the shortfalls and successes, we can further explore the untapped potential of such advancements.

Table of Contents

Early Aerial Photography Archaeological Applications

Prior to photography, early archaeologists relied on some form of local history or lore which pointed archaeologists into a given direction to conduct their excavations and studies. When such sites were located, researchers were forced to use alternate means to obtain different vantage points for their area of interest. Such work was commonly illustrated by drawings of early archaeological sites (American Society of Photogrammetry 1975).

However, with the introduction of the camera came the means for archaeologists to consistently document both the site and their progress visually. Such new technology allowed researchers to take photographs from both the ground and at elevated positions to gain better perspectives of their work environment (American Society of Photogrammetry 1975).

The application of photography applied to archaeology began in the early 1920's when the first known aerial photograph of an archaeological site was taken. This occurred in 1922 when two members of the United States Army Air Service took a photograph of the Cahokia Mounds archaeological site in Madison County, Illinois (American Society of Photogrammetry 1975).

1922 Photograph of Cahokia Mounds taken by Lt. George W. Goddard and Lt. H.K. Ramey (Goddard and Ramey 1922).

Despite such technological advancement in both photography and flight, there was still an issue of practicality. Such photographs were costly and hard to achieve without the proper resources. Therefore, early researchers were forced to look for alternate means of aerial

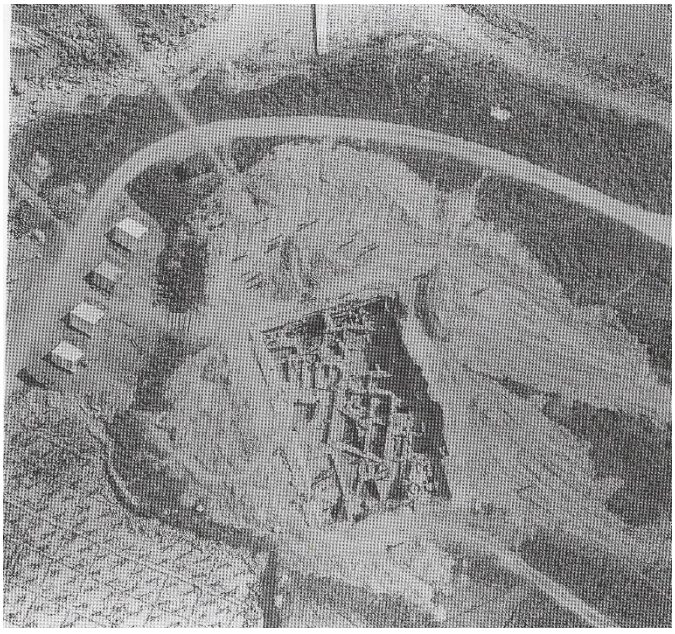
Photograph taken in 1967 by James C. W. Delmege of archaeologist Lorenzo Quilici (Pezzati 2002).

perspectives. Some researchers utilized methods of poles, ladders, kites, and balloons to gain higher vantage points.

However, innovative researchers like Julian H. Whittlesey, architect and archaeologist, came up with new and less expensive ways to take aerial photographs. One such method equipped an 18-cubic meter hydrogen balloon with photography equipment. Whittlesey constructed a lightweight apparatus, so the balloon could carry either a traditional or multi-band camera (American Society of Photogrammetry 1975).

Methods such as this allowed Whittlesey and other researchers to not only track daily progress of site excavations, but also gain a multi-spectral visualization of specific areas of interest. However, this particular method was limited to days where wind speeds were 5 knots or less (American Society of Photogrammetry 1975).

During days where the wind would simply not cooperate, Whittlesey utilized box and para-foil kites to carry cameras. This method of aerial photography allowed for taking pictures when wind speeds exceeded 5 knots. However, such application was limited to a 20-knot maximum and were much more delicate to operate than balloons due to issues with



Balloon photograph taken by Julian Whittlesey of an archaeological site in Sarafand, Lebanon in 1972 (Pezzati 2002).

terrain (American Society of Photogrammetry 1975).

However, as time progressed so did technology. By the turn of the 21st century aerial photography had been completely revolutionized by the birth of the digital camera. Now both professionals and novices alike have the ability to take hundreds of crystal clear images in a short period of time without the restrictions associated with film. This coupled with unrestricted access to unmanned aerial vehicles (UAV's) such as model planes and drones, allows nearly everyone the ability to produce stunning and cost efficient aerial photographs for numerous applications.

Drone Photography in Archaeology

The utilization of drone photography has rapidly become an essential part of archaeological exploration. Many universities from around the world have started using this unique tool, which gives researchers a different vantage point aiding in locating historically significant objects. Professor Jan Driessen of Catholic University of Louvain in Belgium notes; "*The drone is especially useful before we begin digging – giving us a wider view of an entire site, helping us to identify possible areas of interest* (Gutierrez 2016)."

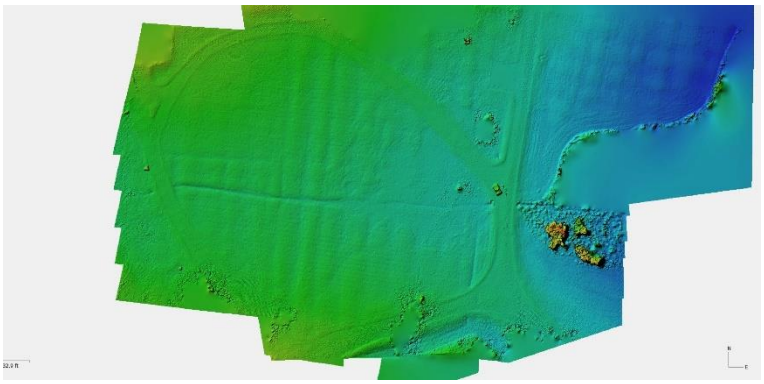
The increased utilization of these aerial photographic platforms can be directly attributed to the device's size, cost, and data storage potential. Such benefits and accessibility now allow researchers the opportunity to easily obtain aerial drones and adapt photographic techniques to conduct site investigations, create 2-dimensional maps, and create 3-dimensional models (Gutierrez and Searcy 2016).

Aerial photograph taken by Austin Valentine Jr. on April 2, 2018 at the Kincaid Mounds archaeological site in southern Illinois.

Second aerial photograph taken by Austin Valentine Jr. on April 2, 2018 at the Kincaid Mounds archaeological site in southern Illinois.

During an interview well-known Architect and Archaeological Survey expert Alfredo Balasco explained his viewpoint on drone photography and modeling, which is based on a structural preservation standpoint. He states "*The relief with the drone allows you to perform measurements in a short time with remarkable precision. It is a*

technology which even in specialized fields such as cultural heritage enables the achievement of excellent results not only in terms of philological relief of the object studied, but also in terms of extremely useful and essential data obtained for the restoration with the possibility of extrapolating from the relief a series of mappings which are related both to the deterioration of the monument but also to the philological reading of it (AnalistGroup 2015)."



Digital elevation model generated from drone photography at the Jamestown Rediscovery site *(Wright 2018)*.

Expressing a similar sentiment to Alfredo Balasco; but focusing more on an entire site preservation rather than individual objects is archaeologist Bob Chartrand. Chartrand is a staff archaeologist at the Association for the Preservation of Virginia Antiquities' Jamestown Rediscovery site. Chartrand notes how much drone photography has aided in exploration of the Jamestown site by giving researchers a different vantage point, further noting how he and his team have been able to create digital elevation models and site maps of the area (Jamestown Rediscovery 2016).

Researchers at an ancient Pueblo site in New Mexico headed by Dr. John Kantner *(St. Fleur 201)*.

However, where drones have initially been utilized to monitor existing sites of archaeological interests, there are examples of drones being used to explore new sites. Archaeologist Dr. John Kantner with the University of North Florida has successfully used

drones to locate lost Pueblo structures hidden below the New Mexico desert (St. Fleur 201).

By equipping a drone with a thermal imaging camera, Dr. Kantner and his team conducted a number of flights over the New Mexico desert just before dawn. He explained, this was the time at which the desert was the coolest, noting that buried ruins had different cooling times than the surrounding sand. Therefore, during the early morning hours they would be most likely seen by thermal cameras. Dr. Kantner's theory proved correct and his findings were published in the Journal of Archaeological Sciences (St. Fleur 201).

Whether it is Alfredo Balasco's cultural preservation, Dr. Kantner's future site explorations, or Bob Chartrand's site management techniques; proof exists of the justified need for aerial drones. The examples above give different applications that are all valid in the field of archaeology. However, as technology advances so will the utilization of tools such as drones as well as their associated software packages.

Kincaid Mounds of Southern Illinois - Initial Site Investigation and 3D Modeling

On April 2nd, 2018 I ventured to the Kincaid Mounds Mississippian Indian Site in Southern Illinois, after confirming the legality of conducting flight operations over the area. My goal in this venture was to collect a number of images from both the air and ground in an effort to construct a noninvasive 3-dimensional model of the site.

Using my DJI Quadcopter 4 Advanced, accompanied with an application called PIX4D (figure 1), I collected a total of 502 aerial photographs. This is the same program that is utilized at the Association for the Preservation of Virginia Antiquities' Jamestown Rediscovery site (Jamestown Rediscovery 2016).

Figure 1 - PIX4D app flight pattern on a mound at the Kincaid Mounds Archaeological Site

Staff archaeologist Bob Chartrand at the Jamestown Rediscovery site places high regard upon the PIX4D program. In a presentation, he explains the program and how it allows a user to establish a grid flight pattern based on an X/Y Coordinate System. Chartrand also illustrates how these images coupled with powerful software such as AGISoft Photoscan can give the operator the ability to conduct site surveys such as maps, 3D models, and elevation models of an archaeological site with relative ease (Jamestown Rediscovery 2016).

My aerial photographs taken on the 2nd were also combined with 355 photographs collected from the ground with a Cannon EOS Rebel T5 digital camera. This was done so that I could obtain multiple vantage points with a variety of focal lengths in an effort to put the software through its paces.

Once these photographs were downloaded, they were then uploaded into image modeling software. The program which I utilized for my graphic modeling was AGISoft Photoscan, which is the same software used at the Jamestown Rediscovery site. This software package provided some amazing graphical editing tools for 3-dimensional applications. The program preformed a number of calculations to create a density plot of the data as illustrated in figure 2. However, the processing time for such applications were extremely lengthy.

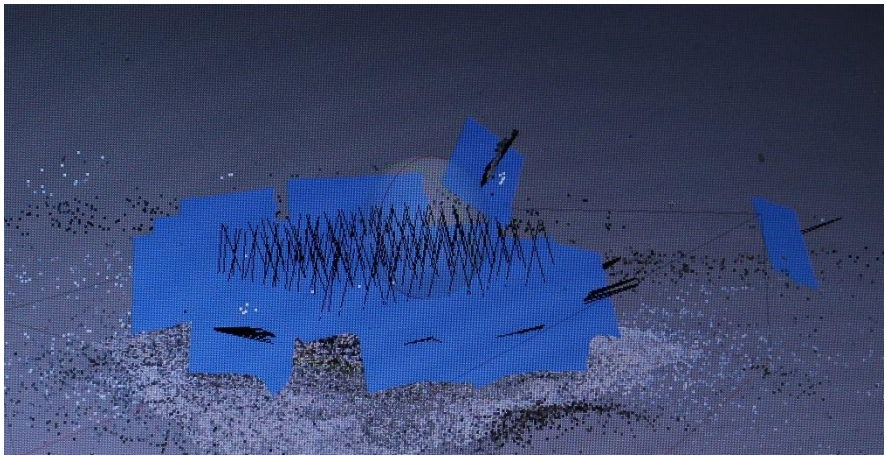


Figure 2 - AGISoft Photoscan Standard Edition's data interpretation of one of the Kincaid Mounds

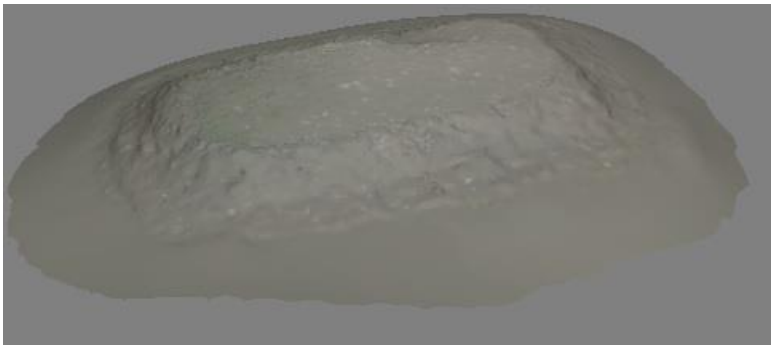


Figure 3 – Mesh application on one of the Kincaid Mounds

Due to the massive processing time associated with the pattern matching and density calculation process, I decided to do each mound individually. Once the density plot was created on my first mound, the next step was constructing what is known as a mesh, which is simply applying a grayscale covering to the model as seen in figure 3.

The final state of model construction is called texturing, which consists of taking visual components of matching pixels to create a photographic finish on the 3-dimensional object. I was very impressed with the final product which is illustrated in figures 4 and figures 5.

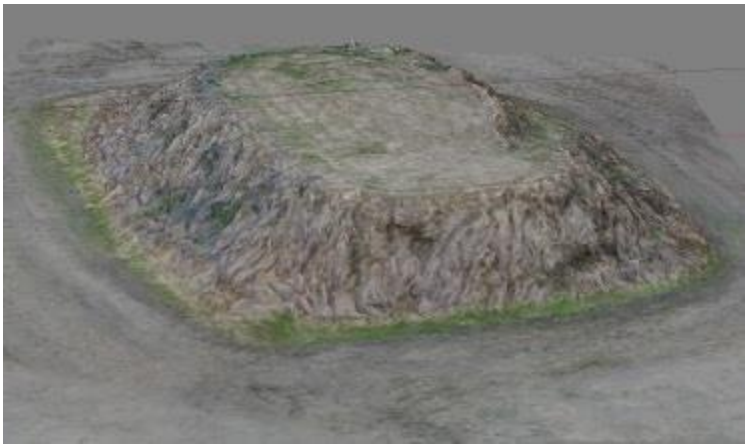


Figure 4 – Front view of one of the Kincaid Mounds

Figure 5 – Top view of one of the Kincaid Mounds

Once the photographic rendering was completed on the first mound, the product was then exported to three different file types;. WRL (VRML – Virtual Reality Modeling Language), .STL (Stereolithography), & .OBJ (Object File). These files are now in the hands of a third party and are awaiting 3-dimensional printing.

The end result of my work will be a scale model of the Kincaid Mounds Archaeological Site. A task that very-well may be the first ever drone constructed model and may even be the first ever 3-dimensional model constructed of the area.

Conclusion

The art of remote sensing through the utilization of drone aerial photography has become a new sensation in the field of archaeology. This new technology coupled with powerful software packages have illustrated that such technology is here to stay. Thus, creating a cost effective and readily available tool that can be operated by nearly any individual while producing professional quality results.

Therefore, as time progresses and technology advances today's society now has the opportunity to create a completely digital rendered world. This allows us to digitally preserve not only items of historical interests, but today's current world view for future generations to examine and become better educated.

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