The author(s) shown below used Federal funding provided by the U.S. Department of Justice to prepare the following resource:

Document Title:	**Detecting and Processing Clandestine Human Remains with Unmanned Aerial Systems and Multispectral Remote Sensing**
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Document Number:	**309829**
Date Received:	**December 2024**
Award Number:	**2019-DU-BX-0027**

Final Research Report

Federal Award Number: 2019-DU-BX-0027

Project Title: Detecting and Processing Clandestine Human Remains with Unmanned Aerial Systems and Multispectral Remote Sensing

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Award Recipient Organization: Texas State University, 601 University Drive, JCK 420, San Marcos, TX 78666-4684

Project Period: 01/01/2020 to 3/31/2023

Award Amount: $286,468

SUMMARY:

Major Goals and Objectives

The major goals of this project were to develop flexible, scientifically based best practices, protocols, and a user interface to aid search teams searching for clandestine human remains and documenting outdoor death scenes using unmanned ariel systems (UAS). The major objectives were to identify the most common environmental disturbances associated with clandestine remains and to determine the most appropriate bands of the electromagnetic spectrum to detect them. The other major objective was to evaluate state-of-the art tools, identify gaps, and determine where/how algorithms can assist experts in detecting clandestine human remains and the associated environmental anomalies.

Research Design

The project was implemented in three concurrent phases. Phase 1 involved data collection and analysis. During this phase we collected, analyzed, and processed data using UAS equipped with a variety of sensors. The sensors include RBG (three bands in visible spectrum), multi-spectral, hyperspectral, red edge, near infrared, and forward-looking infrared. During Phase 2, supervised and unsupervised algorithms were evaluated to understand performance across forensic and environmental contexts to identify capabilities and gaps and to make modifications as needed. Phase 3 included development of best practices and dissemination of the experimental results. This process is ongoing.

Expected Applicability of the Research

A novel approach to the problem of locating clandestine human remains is to use small remotely controlled aircraft or unmanned aerial systems equipped with appropriate sensors. UASs are an emerging technology that has the potential to revolutionize the search for clandestine human remains. First, many UAS sensors (radar, infrared, etc.) detect surface and obscured (e.g., in ground) evidence outside the range of human vision. Second, UASs can help us systematically and safely (i.e., not put an expert at risk) search large areas. Their data can be processed by a computer, involve a human-in-the-loop, or some combination thereof. The advantage to the criminal justice system is UASs equipped with appropriate cameras/sensors can provide a cost- and time-effective method of obtaining an accurate, reliable, and high resolution spatial and spectral output for the discovery and documentation outdoor scenes. The best practices resulting from this research provide search teams with scientifically based procedures to searching for clandestine remains depending on their location (above or below ground level), and stage of decomposition as well as the season and time of day of the search. The user interfaces will aid investigators in analyzing images and help expedite and improve detection of clandestine remains and outdoor death scenes. The protocols developed as part of this project are already being used by law enforcement and civilian search teams to locate clandestine human remains. In the coming years we will hold workshops for law enforcement and civilian search teams on the protocol which will increase the applicability of the research findings.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

No persons working on this grant collaborated with individuals in foreign countries or traveled to a foreign country associated with their role in the project.

Name / Organization:	Daniel Wescott, Texas State University
Project Role:	PI and forensic anthropology expert
Contribution to project	Developed the project and served as project manager.

Name / Organization:	Gene Robinson, Gene Robinson Consulting
Project Role:	Collaborator and UAS and SAR Expert
Contribution to project	Image collection, testing of protocol, and development of best practices

Name / Organization:	Derek Anderson, University of Missouri
Project Role:	Subaward PI, computational intelligence/machine learning expert
Contribution to project	Lead at MU and coordinator of research tasks at MU, tasked with developing the CGSR Data Visualization tool and algorithms for the detection of human remains

Name / Organization:	Bryce Murry, University of Missouri
Project Role:	Doctoral Research Assistant for Derek Anderson
Contribution to project	Assisted Dr. Anderson with drones, sensors, data, and interfaces

Name / Organization:	Alexis Baide, Texas State University
Project Role:	Graduate Research Assistant
Contribution to project	Alexis assists with placement of bodies, collection of ground data, and assisting the PI

Name / Organization:	Sean Haynes, Texas State University
Project Role:	Graduate Research Assistant

Contribution to project	Sean assists with placement of bodies, collection of ground data, and the organization of photographs

Name / Organization:	Eliana Gutierrez, Texas State University
Project Role:	Undergraduate volunteer
Contribution to project	Eliana assists with organization and entry of data and photographs

Name / Organization:	Shane Seitz, Unmanned Systems Research
Project Role:	Software developer
Contribution to project	Developed and marketed the Radiometric Data Tool software.

Name / Organization:	Juan Cantu, Innovative AgriVision LLC
Project Role:	Drone Pilot
Contribution to project	Conducted UAS flights and provided expertise on vNIR.

CHANGES IN APPROACH FROM ORIGINAL DESIGN

Several modifications were made to the original design of the project due to discoveries made early in the project and, most importantly, because of pandemic restrictions during the study period. Two months into the project policies associated with the COVID 19 pandemic went into place. As a result, universities were closed and there were restrictions on travel and public gatherings. One of our collaborators withdrew from the project because of COVID 19 restrictions, and therefore data collection in Missouri and work on the Clandestine Grave and Surface Remains Data Visualization Tool were suspended. Likewise, collection of data using hyperspectral imaging was delayed. Because of the loss of our collaborator, we partnered with Unmanned Systems Research and helped develop the Radiometric Data Toolset. We also learned that locating surface remains and 3D documentation of scenes are both relatively easy and that lots of work, especially in scene documentation, was being conducted by other investigators since we initially proposed the project. Therefore, more time was devoted to research focused on detection of buried human remains than previously proposed.

OUTCOMES

Activities/Accomplishments

Thirty human bodies were placed both subaerial (on the ground surface) and subterranean (below ground) at the Forensic Anthropology Research Facility in San Marcos, Texas. For buried bodies, the temperature of the body, air, grave soil, and soil near the burial were monitored throughout the data collection process. For bodies placed on the surface a thermal camera was used at varying times throughout the day to compare the temperature of the body, the cadaver decomposition island, and the surrounding soil/vegetation. Graves variation included type of equipment (machine versus hand dug), location (open grassland versus tree area), depth, size, and body position (tightly flexed versus extended).

Results and Findings

The use of unmanned ariel systems to aid in the search for clandestine human remains has the potential to save time, money, and resources during casework. The search for clandestine human remains often involves the detection of environmental anomalies. For example, the act of burying a human body causes an environmental footprint that changes over time. Excavating a grave requires mechanically disturbing soil and destroying established vegetation. In the short term, there is a change in soil compactness, moisture, and mineralogy of the grave soils as well as the site being devoid of plants. In the midterm, there will be new vegetation growth on the grave and mounding or depression of the grave soil. Often the first plants to regrow are herbaceous weed species which differ from the surrounding vegetation in species diversity. In the long term, persistent changes in health of the plants are detected by the vegetative index, especially in the growing season, because vegetation has higher reflectance in the very near infrared range but a lower reflectance of red wavelengths. In this study, we examined the most appropriate methods for detecting these environmental anomalies based on the state of body decomposition, season of search, and weather conditions.

Thermal data can be used to detect both subaerial (on the ground surface) and subterranean (below the ground surface or buried). Data examining differences in temperature between the body, grave soils, air, and surrounding soil, for example, provided information about the best time of the day to search for remains, especially using infrared (thermal) sensing. There exists a relationship between the body core temperature, the grave soil temperature, and the surrounding ground surface temperature. For buried bodies, the cadaver follows the same cyclic pattern as the soil and air temperatures but with less variation and a slight lag time. This information demonstrates that early in the morning before sunrise is the optimal time to discover buried human remains that are still producing heat associated with decomposition. The lag between these temperatures can be used to detect bodies using thermal data if decomposition is still active. Likewise, temperature data for surface remains indicates that desiccated skin can exceed the ground surface temperature by greater than 5° to 20°C during peak sunlight hours, which can be detected with longwave infrared sensing. The data collected during this project also demonstrates that days with less cloud cover are more productive for locating desiccated remains on the ground surface. This method is also more effective in warm to hot months of the year.

Another anomaly we noticed associated with clay soil was that when a body in a shallow grave went through bloat (buildup of gases in the body due to bacterial activity), the soil would be pushed up and compressed. When the bloating stage was finished and the body collapsed, a cavity would often form in the soil. In many cases a hole would then form from the surface to the cavity by either rain or animal activity. Using thermal imagery, we observed that in the morning this vent would be warmer than the grave soil but in the afternoon it is cooler. Both of these cases can be detected using infrared sensors.

Since temperature differences can be a key to detecting clandestine remains, we worked in collaboration with Unmanned Systems Research who developed the Radiometric Data Toolkit. This software is now available to search teams and designed specifically to detect even small differences in temperature beyond the background when using radiometric (thermal) imagery. The toolkit allows the user to import radiometric data into several standard palettes. Once this process has been completed, RDT can batch process large volumes of data by user definable parameters. The first parameter is by percentage above the average of the overall data captured. The second user definable parameter is a known temperature range that can be as little as 1 degree.

Buried remains can also be detected using variation in vegetation, which are detectable with red edge and near infrared sensors. Spatial analysis of the vegetative index appears to be a valuable tool for detecting older graves, especially in the growing season. Our findings show that graves and cadaver decomposition islands can be detected for years following disposal of the remains, especially if the search occurs during the growing season when differences in chlorophyll in the vegetation can be detected. In the hot and dry summer months detection is more difficult. In the near future, we will work to develop software similar to RDT for analyzing VNIR imagery to help detect vegetation differences that could help identify a clandestine grave.

LiDAR has the potential to aid in grave detection, but the elevation changes associated with grave mounds and depressions is not distinct enough in most areas. However, we may be able to in the future combine LiDAR and the vegetative index to locate graves more effectively with vegetation cover.

The aid of common algorithms used to perform object detection, such as convolutional neural networks, can help improve the detection of human remains. For example, available algorithms used in self-driving vehicles can be used to detect human shapes on the ground surface from UAS images. However, for badly decomposed bodies the shape of the body may be obscured by the cadaver decomposition island (fluid purged from the body), especially if using thermal imagery. In these cases, a novel "blob" detection algorithm can be used to help detect a CDI, which is detected primarily using near infrared or infrared wavelengths. As libraries increased machine learning techniques will allow for refinement of these algorithms.

Overall, the findings of this study indicate that detection of human remains is not as simple as flying a UAS with a camera. Our findings demonstrate that the protocol used for detecting clandestine remains is highly dependent on how the body was disposed, the season of the year the body was disposed and search for, the decomposition stage of the body, and the local geological and weather conditions. Therefore, search teams must use the appropriate protocols and sensors to successfully locate human remains using UAS. However, the findings also demonstrate that the use of UAS to aid in the search of human remains can be beneficial to search teams. As sensors become more affordable and machine learning procedures improve, software will be able to analyze images in real-time and help assist experts in detecting clandestine human remains.

Limitations

The primary limitation to this study is that it was conducted in one environment. While many of the principles developed should work in other environments, there will need to be modifications made by local search teams based on ambient temperature, soil type, soil moisture, and other factors. In the future we hope to collaborate with facilities in different environments to mitigate some of the limitations.

ARTIFACTS

List of Products

RDT Radiometric Data Toolkit. https://www.usri.ca/ - free standing software which conducts pixel level thermal analysis of images containing radiometric data to detect small temperature changes from the background that can aid in the detection of buried human remains.

Clandestine Grave Surface Remains (CGSR) Data Visualization Tool – Graphical user interface developed by the University of Missouri to run algorithms for the detection of surface remains. The view consists of co-registered spatial and spectral data (e.g., infrared, structure from motion, and hyperspectral).

Forensic Analysis Dashboard – Dashboard developed by the University of Missouri to link weather and ground temperature data with body and grave soil temperatures.

Dissemination Activities

Wescott, Daniel J., Gene Robinson, Derek T. Anderson, Bryce Murray. 2023. Unmanned aerial systems for the search and documentation of clandestine remains. In: Ross A, Byrd J

(Eds), *Methodological and Technological Advances in Forensic Science: Application and Case Studies*.

Wescott, Daniel J. Detection of human remains using remote sensing. Presentation to Texas EquuSearch. June 24, 2023.

Wescott, Daniel J., Gene Robinson, Derek Anderson, Shane Seitz. Discovering clandestine human remains using unmanned aerial system based remote sensing. National Institute of Justice Forensic Science Research and Development Symposium. Virtual Conference, March 2, 2022.

Wescott, Daniel J. Methods for locating clandestine human burials using unmanned aerial systems. Presentation to Federal Bureau of Investigations – Dallas, Emergency Response Team. April 5, 2022.

Wescott, Daniel J. and Gene Robinson. Methods for locating clandestine remains using unmanned aerial systems. GeoForensics Working Group. December 13, 2022