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A novel application of terrestrial LIDAR to characterize elevation change at human grave surfaces in support of narrowing down possible unmarked grave locations☆

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ABSTRACT

Unmarked graves are difficult to locate once the ground surface no longer shows visible evidence of disturbance, posing significant challenges to missing person investigations. This research evaluates the use of terrestrial LIDAR point data for measuring localized elevation change at human grave surfaces. Three differently sized human graves, one control-pit, and surrounding undisturbed ground, were scanned four times between February 2013 and November 2014 using a tripod-mounted terrestrial laser scanner. All the disturbed surfaces exhibited measurable and localized elevation change, allowing for separation of disturbed and undisturbed ground. This study is the first to quantify elevation changes to human graves over time and demonstrates that terrestrial LIDAR may contribute to multi-modal data collection approach to improve unmarked grave detection.

1. Introduction

Globally, millions of missing persons are unaccounted for, and their fates are unknown. Some of the missing are thought to be deceased and buried in unmarked graves. Unmarked human graves can be difficult to locate because their surfaces are often camouflaged through natural processes and/or deliberate concealment. Natural processes include new vegetation growth, dry leaf litter, or other debris accumulation. Deliberate concealment can involve perpetrators attempting to hide a body by mimicking these natural processes.

Locating unmarked graves and potentially associated contextual evidence is important to the families of the missing, for forensic investigations, and for post-conflict accounting of missing persons [6,21]. If located, a grave can be excavated to help reconstruct a narrative of events leading up to its creation [29]. If a grave is excavated, buried remains can be returned to the victims' families or communities, if that is desirable, so the living can perform culturally specific funerary rituals [4]. Without knowledge of the location of an unmarked grave, communities can endure prolonged distress over the unknown status of their missing relatives [17,24,27]. Without physical evidence of their crimes, perpetrators may benefit from impunity [29]. To address these important issues, it is necessary to continue building upon existing methods for locating unmarked human graves.

Witnesses can sometimes lead investigators to unmarked graves, but witness testimony is often imprecise or unavailable. For cases lacking witness testimony, investigators must decide which resources are necessary to help locate an unmarked grave. Other approaches to grave detection include ground-based and remote survey methods. Ground-based methods include pedestrian survey [1,5] or even more invasive and time-consuming methods, such as probing, collecting soil cores, or exploratory excavation [12,25]. While excavation is the only method that can confirm the presence or absence of human remains, it is time and labor intensive and the process is destructive. Excavation is typically used to confirm the location of a human grave once a larger search area has been narrowed through other means.

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Geophysical technologies such as ground penetrating radar (GPR), electrical resistivity, and magnetometry are ground-based methods that can assist with human grave detection by identifying non-specific subsurface anomalies. The common benefits to these technologies are that they are non-destructive and non-intrusive. However, since each sensor is usually operated systematically at the ground surface directly above a grave, the suspected location of a grave must already be somewhat narrow. Additionally, there is a growing body of research demonstrating temporal limitations [18] as well as performance limits in certain soil types [1].

Remote survey technologies are those that do not require people or instrumentation to be positioned at the approximate location of a burial, but within its line-of-sight. Such technologies can include terrestrial (ground stations), aerial (manned or unmanned aircraft), or orbital (satellites) sensing platforms. Researchers are exploring the potential utility of spectroscopy for human grave detection ([8–10,20,22,30]). However, the phenomena driving the spectral separation of human grave materials are still poorly understood. Moreover, spectral signatures are not always scalable to airborne or orbital platforms ([8,30]). Comprehensive remote sensing studies are best supported by ground truth data to establish phenomenology in high spatial resolution, which can be used to inform investigations involving other sensing platforms and environments.

Human graves change the ground surface. No matter their size, every grave contains a combination of disturbed soil and excess mass. Elevation changes at human grave surfaces are described anecdotally in the forensic archaeological literature as the result of initial interment and then the subsequent redistribution of buried mass, resulting sometimes in an apparent surface mound or depression, but sometimes not [3,13,14,23]. In an attempt to capture these changes, LIDAR was previously used to map cemetery grave plots with mixed results [28]. The inconclusive results are likely due to topographic variation (e.g., variable slope, anomalous surface depressions or mounds) that cannot be normalized with a single collection. To date, no one has measured and quantified grave surface elevation changes over time.

The goal of this study is to quantify what we will refer to as “localized elevation change,” a morphological anomaly characterized over time by elevation gain or loss at the surface of human graves and a grave-like disturbance pit (control), relative to surrounding undisturbed ground. We hypothesize that elevation change at each disturbance surface is localized (i.e., observable to the horizontal extent of the disturbance) and measurable, and that the direction and magnitude of elevation change will correlate with naturally occurring and time-dependent factors, such as body decomposition, soil settling, and organic debris accumulation throughout the study area. The findings of this study may help identify signatures that can be used to isolate areas of disturbance, including unmarked burials, from their undisturbed surroundings. Our aim is that this study will ultimately support the narrowing down of possible unmarked grave locations.

2. Material and methods

2.1. Study area

This study was conducted at the University of Tennessee’s outdoor Anthropological Research Facility (ARF), operated by the Forensic Anthropology Center (FAC). The study area is a controlled, natural, and undeveloped environment to simulate a clandestine grave scenario and had not been previously used for forensic research (Fig. 1). The ARF is located on the south bank of the Tennessee River in Knoxville, TN and its perimeter is bound by two nested security fences. The landscape is densely populated with mixed tree, underbrush, and grass species of both native and non-native origins, with primarily topsoil (0–10 cm below surface) and red clay (10+ cm below surface). During Spring and Summer seasons, the dense tree canopy obscures the study area view from above. During Autumn and Winter seasons, the study area is visible through the canopy, but decomposing organic debris covers the ground surfaces.

2.2. Human graves

During 13–15 February 2013, four pits of different sizes were hand-dug in level ground using shovels and pickaxes (Table 1, Fig. 2). Three pits contained individuals who donated their bodies for research to the FAC Body Donation Program. One grave

Fig. 1. The study area, adjacent to the William M. Bass Forensic Anthropology Building (west) and the Tennessee River (northeast) in Knoxville, TN. Image: Google Earth.