Terrestrial Laser Scanning and the Post Mortem Interval

Remote sensing technologies have recently emerged in forensics as a way to investigate clandestine graves and crimes scenes, as methods tend to be both nondestructive and noninvasive[1]. Specifically, the use of terrestrial laser scanning (TLS) for forensic investigations has increased significantly. TLS has the unique ability to rapidly characterize the environment around the scanner in 3D with high accuracy and fidelity that allows the development of a virtual model of the area of interest. As a result, TLS technology is being routinely used in a number of jurisdictions for crime scene documentation, as well as accident documentation and reconstruction. In cases involving death, the use of TLS has mostly focused on gathering evidence from the crime scene, and has not been used to study the state of victim for accurate determination of post mortem interval (PMI).

Figure 1: Southeast Texas Applied Forensic Science Facility at Sam Houston State University

Deep in the primordial forest of eastern Texas, at the Center for Biological Field Studies located in Huntsville, TX, Aaron Lynne and Sibyl Bucheli watch as Craig Glennie starts his first lidar scan. Glennie remarks that this might be, nope, definitely is the oddest thing he has ever scanned. What he is scanning is a cadaver that has just been placed outdoors to decompose at the Southeast Texas Applied Forensics Science (STAFS) facility at Sam Houston State University. The STAFS facility is a state-of-the-art human decomposition facility whose mission is to advance academic and technical knowledge in the application of forensic science through research, education, and training. STAFS is one of only four facilities worldwide equipped for studies of human decomposition. Such facilities help to investigate criminal cases by allowing recreation of past scenarios, but also provide a unique location to develop skills for future investigations by providing resources necessary to conduct basic research in a discipline that remains severely under studied.

Bucheli and Lynne are primarily interested in understanding the basis of human decomposition as measurable chemical and biological processes. As a cadaver decomposes, it passes through several major stages leading from wet decomposition (fresh, bloat) to dry decomposition (decay, mummification, and/or skeletonization.) The purging of

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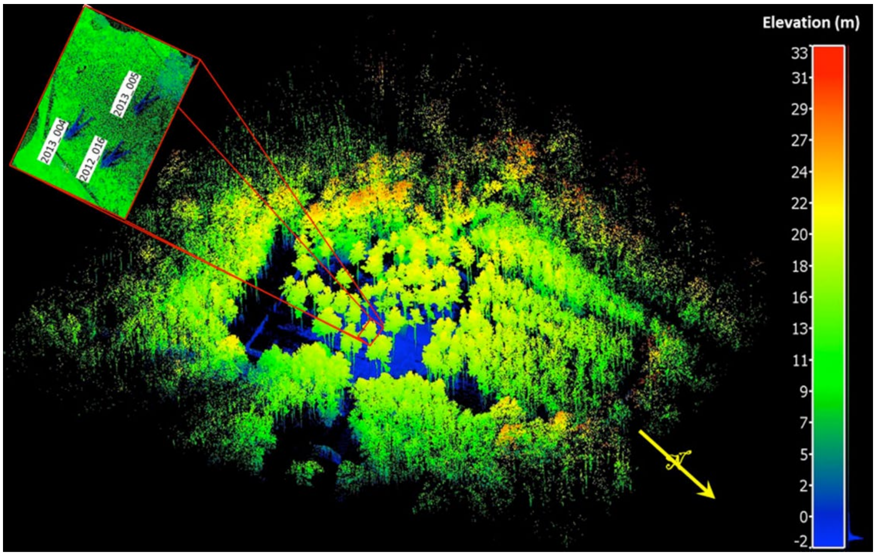

Figure 2: TLS point cloud for irradiance studies at STAFS. Inset image shows placement of cadavers (after [2]).

body fluids usually marks the end of the bloat stage when the body cavity begins to collapse and the shift from wet to dry decomposition. Using clues provided by the body, such as bloat or degree of desiccation, a forensic scientist works backward through time to estimate the PMI. Though predictable to a degree, alteration of temperature, humidity, rainfall, or soil conditions may change the tempo and mode of decomposition, allowing a cadaver to experience multiple stages of decomposition at once, bypass a stage, or prolong a stage[2], all of which could lead to misinterpretation of the PMI.

Decomposition is also greatly facilitated by organisms adapted to consume decomposing tissues. Obligate necrophagous feeders such as bacteria and blow flies can only complete their life cycle on decomposing tissues. They exist in strong competition for limited resources, which results in a complex ecological scenario that, if understood, can provide historical information. Obligate necrophagous feeders will capitalize on the cadaver at different stages of decomposition. This resource specialization and partitioning results in ecological succession—a predictable change in the community structure that is driven by the cadaver ecosystem shifting from wet to dry. Once patterns of succession are understood, this information can be used in models to estimate time. Strengthening basic research in biology and chemistry, as well as incorporating novel techniques, should yield refined techniques to more accurately estimate the postmortem interval.

The bacterial community using a cadaver as a resource remains largely unexplored. In collaboration with Joseph Petrosino at Baylor College of Medicine, we are in the process of cataloging bacterial diversity through time by molecular identification techniques. Presence, and absence, of particular bacteria at particular time points during decomposition should tell us to what stage of decomposition a cadaver has progressed and therefore the time since death. After bacterial succession is understood, conditions of decomposition can be altered (aquatic, full sun, indoors) and we can record community structure and its influence on the tempo and mode of decomposition under each new scenario. These analyses will result in a detailed model incorporating not only necrophagous community structure but also aspects of the ecology that could have led to an altered trajectory of decomposition.

One challenge that we have faced is assessing quantitatively the impact an ecosystem has on a cadaver. Accurate measurements of ecosystem components combined with qualitative assessments of the cadaver will allow scientists to gauge progression through stages of decomposition more precisely. Additionally, understanding the degree to which cadavers experience particular stages of decomposition, such as bloat or degree of desiccation, can further advance the field.

Our challenges have been met through the use of terrestrial laser scanning to measure aspects of the cadaver as well as ecosystem components. One of the biggest drivers to ecosystem change is the amount of solar irradiance a site receives. For a cadaver in an open field, the effect of irradiance is easily predictable, with the use of weather observations, including sky conditions, temperature, relative humidity and time of year.

However, in a forested environment obtaining an accurate measure of irradiance can be quite difficult due to the uneven shading provided by trees and other vegetation. This is where TLS becomes an important tool. By acquiring a 3D point cloud of the environment surrounding a cadaver (**Figure 2**), a virtual world is created in which solar illumination for a given day, week or

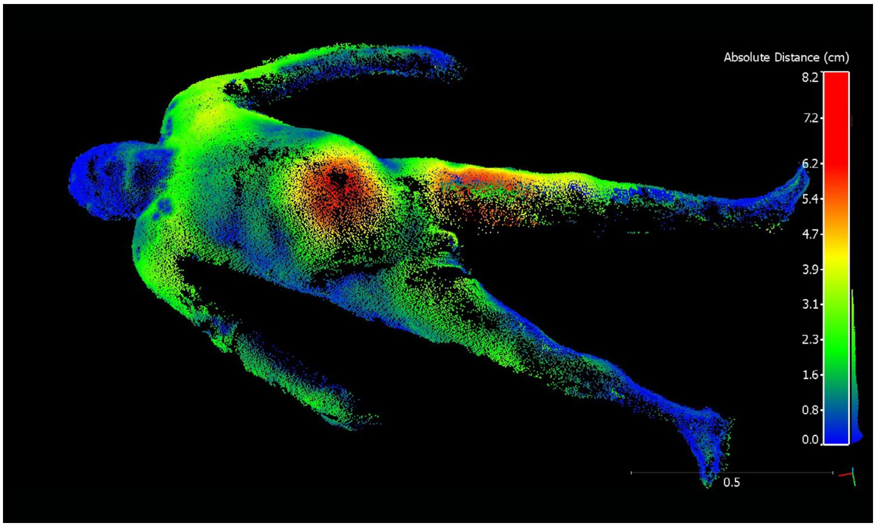

Figure 3: Volumetric Change of Cadaver over two days. Red indicates expansion (bloat).

month can be predicted using the known trajectory of the sun through the sky, ray tracing and occlusion identification[3]. Using these techniques, a map of solar irradiance for every portion of the cadaver can be obtained as a predictive tool for changes in ecosystem during decomposition.

Further to understanding the ecosystem, we are also attempting to document volumetric changes the body is undergoing[4] during decomposition (**Figure 3**). This is accomplished by repeated scans of the cadaver over the active portion of the decomposition process (bloat and purge). Here, we hope to link tempo and mode of decomposition to aspects of the cadaver ecosystem, such as degree of bacterial metabolism relative to temperature. Already, even though in the preliminary stages of analysis, we have been able to document that limbs (which goes against traditional thought[2]) as well as the torso experience bloat. By conducting controlled experiments where this ephemeral process can be measured relative to accumulated temperature received by the cadaver ecosystem, we can begin to understand the bacterial influences on the event.

Presently, we have only shown that TLS can be used to create irradiance maps, and provide accurate volumes for gross morphological change during decomposition. However, we have not yet established a definitive linkage between the virtual models and the biotic and abiotic processes at work on the cadaver. The difficulties associated with studying human decomposition are dependent upon many factors and the route taken to get to the end stage of skeletal remains can vary based on specifics of the ecosystem of decomposition.

Our long-term goal is to be able to provide a model for decomposition that accounts for the mosaic nature of the process. To do this, ecology and its effect on decomposition must be measured. TLS has been useful in quantifying solar irradiance and gross morphological changes experienced by the cadavers. The National Research Council's Committee on Identifying the Needs of the Forensic Sciences has called for research in basic science to unite disparate disciplines of forensic biology and fill a multidisciplinary knowledge gap where data is severely lacking. Our research does this by holistically studying human decomposition from a measurable ecological perspective.

References

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