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# Locating and Mapping Missing Cemeteries in Immersive Virtual Environments

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**Abstract:**

Cemeteries are unquestionably significant sites. The places people are buried mark historic moments, cultural traditions, and belief systems, where individuals and communities can gather to connect to the past. These sacred sites transcend any one culture, religion, or nationality, and serve as reminders of the inevitability of death and our shared human experience. Even though cemeteries are important heritage sites, cemetery preservation is not a certainty. Cemeteries are under constant threat from environmental, e.g., erosion and flooding, and human factors, e.g., development, vandalism, and neglect. One of the greatest threats and challenges cemetery preservationists contend with is locating lost cemeteries.

Cemetery locations are lost when institutions responsible for maintenance are closed or relocated, records related to these properties are destroyed, or the interred individual's descendants move away. Often, lost cemeteries are the final resting places of disenfranchised people who are already historically underrepresented. Losing these cemeteries is a further mark of disrespect and discrimination towards both the people buried in these sites and their descendants. Locating lost cemeteries is important to ensure the histories of these people are not erased, but finding forgotten cemeteries can be a challenge. The traditional techniques and tools archaeologists use to locate cemeteries, e.g., cemetery delineation and mapping, ground-penetrating-radar (GPR), and cadaver dogs, are expensive, time-consuming, and not always successful. It becomes even more difficult to identify cemetery sites in areas that are overrun with dense vegetation or in remote, inaccessible locations.

Archaeologists use remote sensing technologies, e.g., light detection and ranging (LiDAR), to help identify archaeological sites and related features in overgrown and remote areas. Features are defined in an archaeological context as non-portable components of sites, e.g., walls, hearths, and graves. Archaeologists can often detect large-scale features, e.g., roads, irrigation systems, and earthworks, in publicly accessible LiDAR, sometimes offered by local and federal governments. In recent years, archaeologists have been able to identify small-scale site features, e.g., graves, in higher-density LiDAR data collected using unmanned aerial vehicles (UAV) outfitted with LiDAR systems. These small-scale site features are often undetectable in lower-density LiDAR. However, access is limited to UAVs with LiDAR due to factors like high-expense and remote-pilot requirements.

Immersive virtual environments (IVE) provide opportunities for researchers to investigate LiDAR data from alternative perspectives. In an IVE, users are immersed in the landscape, interacting with the environment through a virtual avatar. Users can move around the IVE similarly to how they interact with real-world space. In an IVE, issues archaeologists encounter in the physical world that can obscure feature detection are removed, e.g., dense vegetation, challenging terrain, and site inaccessibility. Unimpeded by these obstacles, the IVE user can investigate the terrain and focus on specific tasks, such as feature detection.

This research introduces a feature mapping methodology for archaeologists working in IVEs. This work details IVE map development in the Unity Game Engine using LiDAR. It describes a feature mapping process using virtual avatars in an Oculus Rift head-mounted display (HMD), operated using Oculus Touch hand controllers. Archaeologists tested this mapping methodology on two IVE site maps a) a well-delineated cemetery and b) a cemetery of uncertain location and unknown extent. The results of this mapping process were compared with feature detection analysis completed in a more traditional desktop environment. Preliminary findings suggest that feature detection and mapping in IVEs may be an important tool for archaeologists searching for lost cemeteries and working to bring hidden histories to light.

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