Point Clouds via Terrestrial Laser Scanning as a Digital Scaffold for Archaeological Visualization

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Aerial photography, traditional photography, and a point cloud model of the copper mining site of Khirbat Faynan in southern Jordan.. These visualization techniques can be layered together with textual, geographical, and data collected during archaeological excavations to archive and disseminate the data for analysis.

Introduction: As humanity's capabilty to collect larger and larger data sets increases, it is imperative that a means to organize and visualize this data be created and standardized. It is particularly important that the layers of cultural heritage data which can be generated with reference to archaeological sites, historic monuments, and classic artwork be preserved- as these are constantly in threat from environmental and ecological forces. The University of San Diego, California's Center of Interdisciplinary Science for Art, Architecture, and Archaeology (CISA3) is working to combine these two goals by creating informatic visualization systems which are founded on diagnostic cultural heritage data (1). My research focuses on establishing ways to collect and utilize a point cloud scaffold via terrestrial laser scanning which can act as the architectural scaffold onto which all other data can be built.

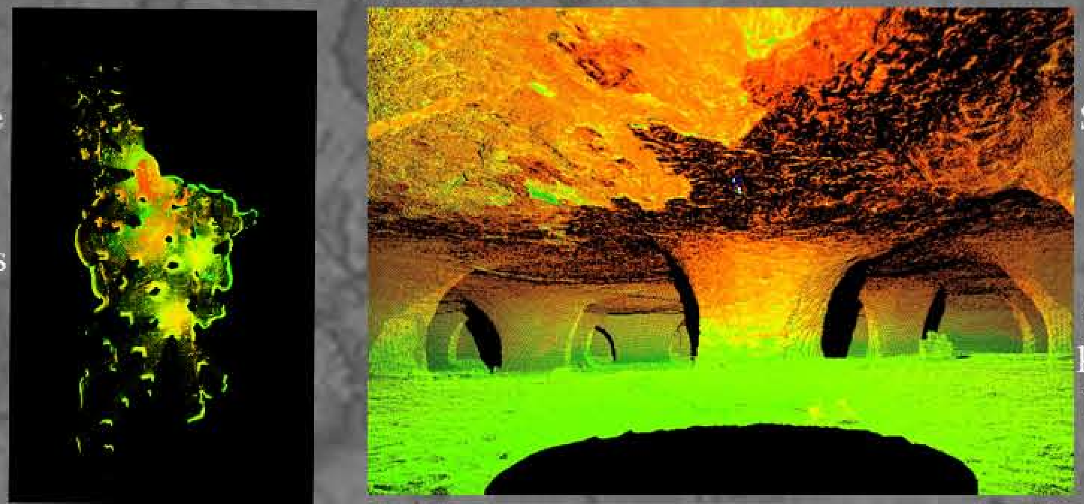
Re-Engineering the Laser Scanner

At Left: A Leica ScanStation2 terrestrial laser scanner pre and post tilt head adjustment.

Terrestrial Laser scanning or LiDAR (light detection and ranging) is a remote sensing technique which utilizes a time of flight algorithm on a reflected laser pulse to collect geospatial points which form a point cloud representative of the space that was scanned. As it can create a highly detailed replica, it is the perfect base visualization upon which to build a layered system of information. Though aerial LiDAR is often used in archaeology, the rigid machinary and time consuming methodologies associated with terrestrial scanning have limited its use for field surveys and excavations. My initial research focused on ways to speed up the scanning process through adjustments to the scanner's mobility through a smaller, heavy duty tripod which allows the scanner into small spaces and adjustments to the scanner's calibration process, which allow the scanner to be tilted up to 45 degrees on a specially crafted tripod head- allowing the scanner to look down into excavation trenches, reducing the number of scans and scanning time needed to produce similar results.

Rescue LiDAR

At Right: Screenshots of Umm al- Amad point clouds from above & within the mine.



Prior to testing scanning systems in the field as part of the UCSD Edom Lowlands Regional Archaeological Project at their Middle Eastern field school, metadata standards were specifically designed for the data collection and data processing of point clouds collected in the field. A methodology of data capture emphasizing the ability to traverse wide landscapes for surveying was also created. Initial tests of the new systems at Khirbat Faynan in Jordan in 2011 were successful and resulted in a point cloud comparable to the fifteen hectare landscape of the full site. The astonishing speed with which data collection occured resulted in terrestrial scanning being implemented at Umm al-Amad, an endangered Roman copper mining site deep in the Sharra mountains of Jordan. As the site has since been dynamited by nearby road construction, the survey data collected of the interior of the mines is now the only spatial record of the site in existence. Rescue archaeology to salvage documentation of imminently endangered cultural heritage can therefore be successfully conducted with the new speedier Rescue LiDAR (2).

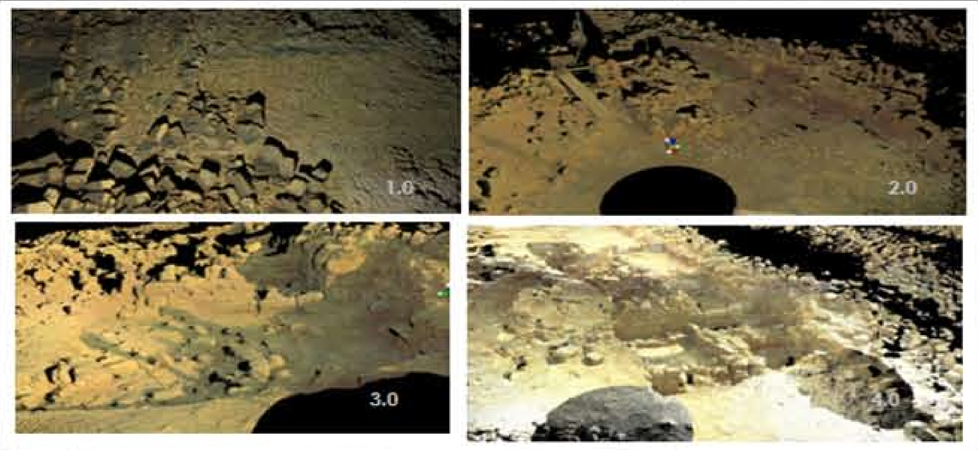
Sandcastles for Science

At Right: A Leica ScanStation2 at Torrey Pines beach, San Diego & a screenshot of a point cloud of a test sandcastle.

Sediment Intervals and Site De-Formation Processes: Exploring Time Lapse Laser Scanning Capabilities for Archaeology took laser scanning to the beaches of San Diego, California to further explore methodologies for laser scanning time lapse data, as well as investigate the scanner's capabilities for scanning high resolution pockets of sediment (a welcome digital record for cyberarchaeological interpretation if it could be done). Unfortunately, tests proved that while time lapse scanning could be methodologically conducted, scanning sediment would require the integration of additional data capture techniques into the scanning workflow to compensate for the scanner's incapcity to capture granular matter. Structure from motion (creating low density point clouds from computational photography) has now been established as a simultaneous technique in the CISA3 workflow to enhance the point cloud's photogrammetry towards being able to visualize sediment detail.

Temporal Scanning

At Right: A sequence (clockwise) of temporal scans depicting the excavation of Khirbat Faynan.



Having been established as a valid methodology in the lab and on the beaches of the US, time lapse scanning, or temporal scanning, whereby the same spatial data is collected repeatedly to reflect change (useful in archaeology to track site erosion or the process of excavation itself) was further refined during the 2012 UCSD field school excavation season. The excavation process at a late Roman period phase at Khirbat Faynan was documented via point cloud so that in addition to contemporary spatial analyses, future archaeologists have a three dimensional record of the excavation in process. However, despite the success of the data- working collection into the workflows of an ongoing excavation was extremely difficult and presented a cadre of hurdles which will have to be overcome before temporal scanning can be implemented as a standard excavation practice. Additional visualization and archival issues which have also now been identified will need to be solved prior to widespread useage in diagnostic data capture practices.

Rapid Documentation for Diagnostic Conservation

International interest in the scanning methodologies constructed as part of ongoing research led to an invitation from the American Center of Oriental research to rapidly digitally document the Temple of the Winged Lions at the UNESCO world heritage site of Petra in Jordan as part of their ongoing conservation project. In the single possible field day allotted for scanning, the Temple of the Winged Lions and the nearby Byzantine Mosaic Church were both documented (3). To pursue the possibility of creating 3D diagnostic maps of paintings and mosaics like those encountered at Petra, current research is being conducted into how to implement structured light scanning into a field workflow as part of the integrated data capture systems to further augment point cloud bases for data scaffolding.

At left: A screenshot of the point cloud of the Petra Byzantine Church mosaics. At right: a collaborative visualization wall displaying Khirbat Faynan data at UCSD.

Archaeological Visualization

Point clouds provide a dynamic visual medium in which the past can be made visible in the present. Systematically collected point clouds can provide the initial, accurate canvas on which additional layers of data can be annotated. CISA3 is pushing the envelope in not only developing new immersive and augmented reality systems in which to colloborate and disseminate cultural heritage data, it is innovating by establishing new methods of data collection. Whether we are surveying our past or surveying the stars, big data sets need to be collected, collated, diagnostically utilized, and transparently shareable. The methodologies and integrated technologies created and tested under the auspices of this research will aid in building a better, visual format for understanding and organizing our world.

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For more information, please check out my 2013 NSF-IGERT video or the CISA3 webpage http://cisa3.calit2.net/cisa3/

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