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Scientific visualization, 3D immersive virtual reality environments, and archaeology in Jordan and the near east

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Author:
Knabb, KA
Schulze, JP
Kuester, F
Defanti, TA
Levy, TE

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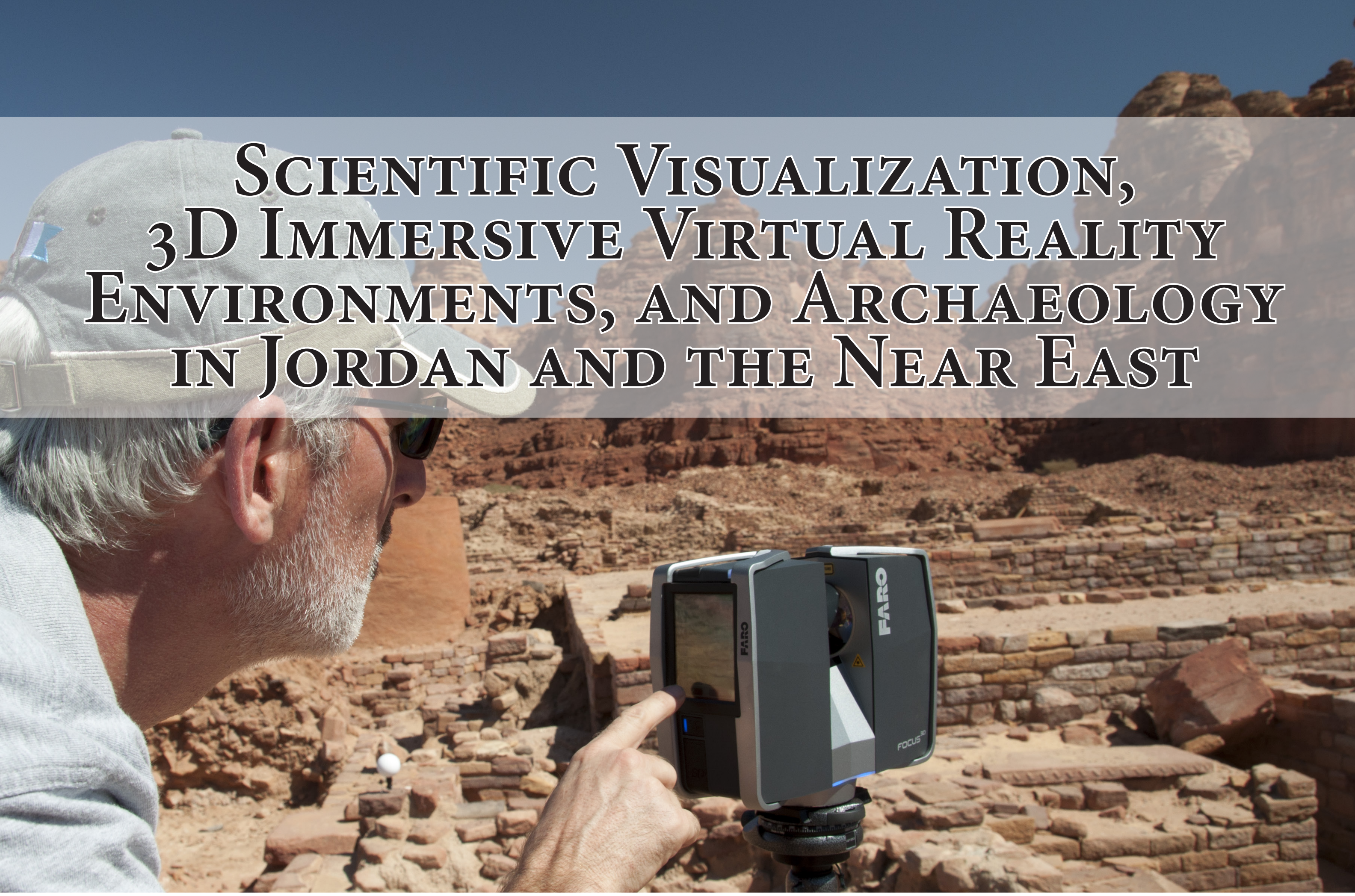
Abstract:
Archaeological data is perfectly suited to 3D modeling and visualization. The geographical remoteness of many heritage sites means that few will ever be able to experience them firsthand. For centuries, practitioners of archaeology have meticulously drafted maps and illustrations, and captured photographs of sites and landscapes (Sanders 2014). Two-dimensional maps and photos reflect scale but never fully embody it. Hence, one of the goals of virtual reality modeling is to take another step toward bridging this gap. This article presents a variety of

Scientific Visualization, 3D Immersive Virtual Reality Environments, and Archaeology in Jordan and the Near East



Collecting point cloud data with Faro laser scanner at Dedan, Saudi Arabia, for dissemination in 3D environments.
Photograph by T. E. Levy, UC San Diego Levantine and Cyber-Archaeology Lab.

Kyle A. Knabb, Jurgen P. Schulze, Falko Kuester, Thomas A. DeFanti, and Thomas E. Levy

Archaeological data is perfectly suited to 3D modeling and visualization. The geographical remoteness of many heritage sites means that few will ever be able to experience them firsthand. For centuries, practitioners of archaeology have meticulously drafted maps and illustrations, and captured photographs of sites and landscapes (Sanders 2014). Two-dimensional maps and photos reflect scale but never fully embody it. Hence, one of the goals of virtual reality modeling is to take another step toward bridging this gap. This article presents a variety of ways archaeologists, working closely with colleagues from computer science, visual arts, and engineering, have worked toward disseminating archaeological datasets to professionals and non-professional audiences alike through virtual reality.

As previous articles in this volume have demonstrated, for those of us working at the University of California, San Diego's Qualcomm Institute (henceforth QI), scientific visualization is one part of a larger process of data acquisition, processing, analysis, archiving, and dissemination (Levy et al. 2010). For audiences of all backgrounds, the virtual reality environments being developed at the QI provide users with a unique and embodied perspective in which the excavator or presenter has control over much of the shared experience. This facilitates visualization demonstrations in which the tour guide may provide narration and engage users in dialog about any questions that arise, archaeological or otherwise.

The virtual reality environments are capable of handling many types of data, including polygonal models, point clouds, stitched imagery, and a combination of these using software developed at the QI. While previous contributions to this volume have detailed how the data for 3D modeling is obtained (e.g. photogrammetry, LiDAR, GIS & GPS, and other methods), here we describe where the archaeological data is displayed and how it is presented. At the QI we employ three virtual reality CAVE environments for displaying archaeological datasets from the Near East. Cave Automated Virtual Environments, or CAVEs, are semi- or fully-immersive virtual reality systems constructed from multiple screens displaying stereo images. These stereo images are then separated into the left and right eyes by polarized glasses worn by users. This way, a 3D stereoscopic perspective is created that mimics the way humans see in 3D in real life.

Three research goals have guided our research with each of the CAVEs. First, our virtual reality modeling aims to display compelling visual imagery using a variety of datasets. This includes excavation data, digital images, site reports, remote sensing, etc. Doing so is an important and efficient way to disseminate complex information in a manner that is straightforward and comprehensible (Forte and Siliotti 1997; Barcelo et al. 2000). Furthermore, researchers are able to revisit excavation areas at a variety of scales, ranging from an entire region to a single excavation unit and the artifacts recorded there.

Second, we aim to use these virtual reality environments as heuristic tools. By visualizing archaeological sites using virtual reality one is able to revisit the site and data again and again without ever going back to the field. In this manner we can investigate the topological and spatial relationship between artifacts, features, ture, and locus is, in a manner of speaking, put back together again. Additionally, the incorporation of GIS databases into the virtual reality model imparts the archaeologist with the ability to perform spatial and statistical analyses similar to the tools available in standard GIS programs.

Case Studies from the Field and Beyond

The StarCAVE is a 5-wall and floor-projected virtual reality system (Defanti et al. 2009). The 360-degree room has a diameter of about 3 m and a height of about 3.5 m. It uses 34 high definition projectors to generate passive stereo images on 15 wall screens (rear-projected to eliminate shadows) and the floor (down projected). We use a multi-camera and 3D input device wireless tracking system to navigate and interact with the StarCAVE (fig. 1).

Figure 1. The StarCAVE at UC San Diego's Qualcomm Institute, showing the 360 degree, five-walled, fully immersive virtual reality system. This image shows the 3D model of the Iron Age copper smelting site Khirbat en-Nahas. Photograph courtesy Qualcomm Institute, UCSD.

and other areas of the site and how these changed through time.

Third, we have experimented with integrating Geographic Information Systems (GIS) with the virtual reality environments. GIS programs, such as ArcView and QGIS, allow the user to browse, query, and manipulate the database on a personal computer. Though still in a state of infancy, the spatial tools we have implemented in the virtual environments allow users to create basic queries and display contextual information about specific artifacts and archaeological sites. Virtual reality technology such as the StarCAVE does, however, operate in a three-dimensional virtual world, and is sophisticated enough to simulate a "real" environment. The precise location of each recorded artifact, fea-

Our research in the StarCAVE has focused on integrating our excavation data from the Iron Age copper smelting site in southern Jordan, Khirbat en-Nahas, into the virtual reality environments (Levy et al. 2008). This involved taking the digitally recorded excavation data, field photography, and other field notes, and reconstructing the topography, architecture, and other archaeological features in Google Sketchup, where we built a 3D polygonal model from the ground up. To model architectural features we began by exporting the two-dimensional polygons of the buildings from ArcGIS to Sketchup. When these files were imported into Sketchup we began to extrude the building footprints to the height of the walls as recorded in the field. To texture the building models with photographs of the actual walls we cropped the digital site photos to include just the architecture. Once cropped and adjusted the images were imported into Sketchup as a texture and matched to a wall face.

The archaeological site is situated in a 3D terrain based on satellite remote sensing data derived from NASA's ASTER global digital elevation models. The terrain model was cropped to include the area around Khirbat en-Nahas and exported to Sketchup. The terrain was then draped with a satellite photo from Google Earth. It is worth noting that getting the terrain model into the 3D model required some extensive modifications that we do not have space to describe here.

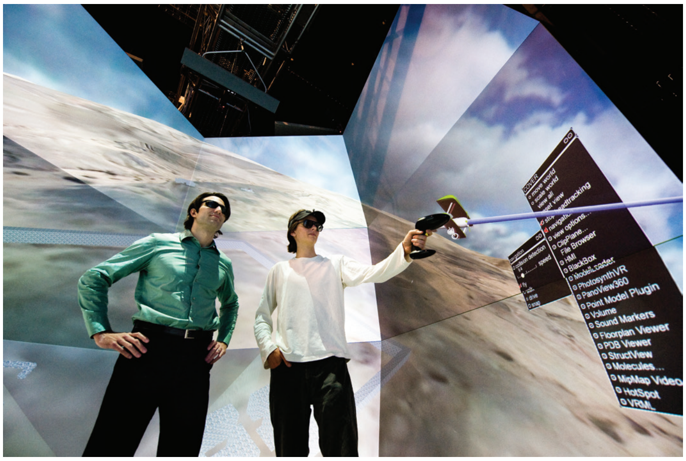


Figure 2 (above). Authors Knabb and Schulze interacting with the Artifact Viz plugin to display artifact information.

Figure 3 (below). The TourCAVE is a parabolic, semi-immersive virtual reality system. This image shows the mosaic floors of the Byzantine church at Petra in southern Jordan. Photographs courtesy Qualcomm Institute, UCSD.

For visualization of artifacts we developed a plugin for QI's virtual reality software CalVR (Schulze et al. 2013). This plugin is called Artifact Viz (fig. 2). The plugin displays the artifacts as differently colored spheres based on artifact types. These spheres are selectable, and when the user clicks on one using the wireless navigation wand, the plugin displays photographs and contextual information for each artifact, which resides in an extensive data bank for the excavation site (Smith at al. 2013a). The plugin also has spatial selection and querying tools for displaying particular artifact types or categories, a variety of selection options (by location, by drawing a box, etc.), and measuring distances. These features can be useful for archaeologists revisiting their data, or for general audiences during a demonstration.

The combination of digitally recorded excavation data, satellite remote sensing, and field records has made it possible to use the StarCAVE as a tool for revisiting our datasets. The Artifact Viz plugin we created provides the user with a number of heuristic options, such as the ability to display artifacts in their original spatial location. The benefits of this reconstruction are the ability of researchers to integrate many data types into a visually compelling, immersive, and interactive virtual reality environment.

The TourCAVE is a partially immersive virtual reality environment consisting of 14 65" LG 3DTVs turned on their sides (DeFanti et al. 2014). At roughly 3.3 m in height, the semi-cylindrically shaped TourCAVE is an ideal system for demonstrations because the 3DTV panels provide sharp, bright and high contrast imagery and are easier to maintain than the projector-based StarCAVE. Users interact with the TourCAVE using a 3D mouse and a dual camera wireless tracking system. The ideal location for viewing in 3D without distortion is at a point at the center of the cylinder.

Among the many data types we display in the TourCAVE are point clouds, derived from LiDAR scans, Structure from Motion, and others. During the 2012 season of the Edom Lowlands Archaeology Project, LiDAR scans were carried out at the Byzantine church in Petra (fig. 3) and visualized in the TourCAVE. Unfortunately, with LiDAR scans there are often gaps or holes in the data where the instrument was unable to collect data. Structure from Motion (Tomasi and Kanade 1992) offers a way around this issue, as the process creates 3D models from digital images taken with a handheld camera from many different locations. Figure 4, for example, shows a model of the late Neolithic/early Chalcolithic site Wadi Fidan 61 in southern Jordan. These images were taken with ELRAPs aerial balloon system for capturing aerial photographs.

Figure 4. A model of the site Wadi Fidan 61 is demonstrated in this image of the TourCAVE. This model was created using Structure from Motion. Photograph courtesy Qualcomm Institute, UCSD.

The WAVE display, true to its name, is shaped like an ocean wave, with a curved wall consisting of 35 55" LG LCD monitors that form a "crest" above the viewer's head and a "trough" at his or her feet (fig. 5). An acronym for Wide-Angle Virtual Environment, it is over 4 m long by nearly 3 m high. Similar to the TourCAVE, users interact with the WAVE using a 3D mouse and multi-camera wireless tracking system. However, unlike the TourCAVE, viewers in the WAVE are able to view 3D imagery without distortion along the entire width of the system, rather than from a single point in the room.

As with other systems, a wide variety of data types are visualized in the WAVE, including 3D imagery from the CaveCam system described in other articles in this volume. This 3D modeling method creates a 3D panoramic perspective from digital images, but from a fixed location (Smith et al. 2013b; Vincent et al. 2013). Thus, unlike other modeling methods, this does not allow users to wander freely through the model. This system was employed during a field project at one of the copper mining districts in northwest Saudi Arabia (fig. 5). Given the high contrast displays and wide dimensions of the WAVE, this system is an ideal one for giving public demonstrations.

Looking to the Future

One of the major theoretical issues with using virtual reality to inform archaeological thinking is how to address the subjectivity involved in reconstructing a site. A crux of the problem lies in the tendency of some to consider a virtual site as an objective reality, when what is really going on is the representation of a perceived past reality that is informed by the creators' own theoretical positions and cultural sensitivities. Our research with the virtual reality environments presented here are first and foremost a reconstruction of the excavations; not an attempt to rebuild the site as we think it was 3,000 years ago. Much of our research in virtual reality differs in many ways from other projects in what we aim to achieve: a virtual record of our excavations and field sites in a system that is highly visual and interactive. It is our hope that these goals will lead to new avenues of analysis and interpretation.

While virtual reality (VR) systems have become more accessible and relatively affordable over previous decades, the systems still require significant infrastructural investments and high costs. Virtual reality has benefits for researchers and general audiences alike, despite these costs. In some ways, this also highlights a cru-

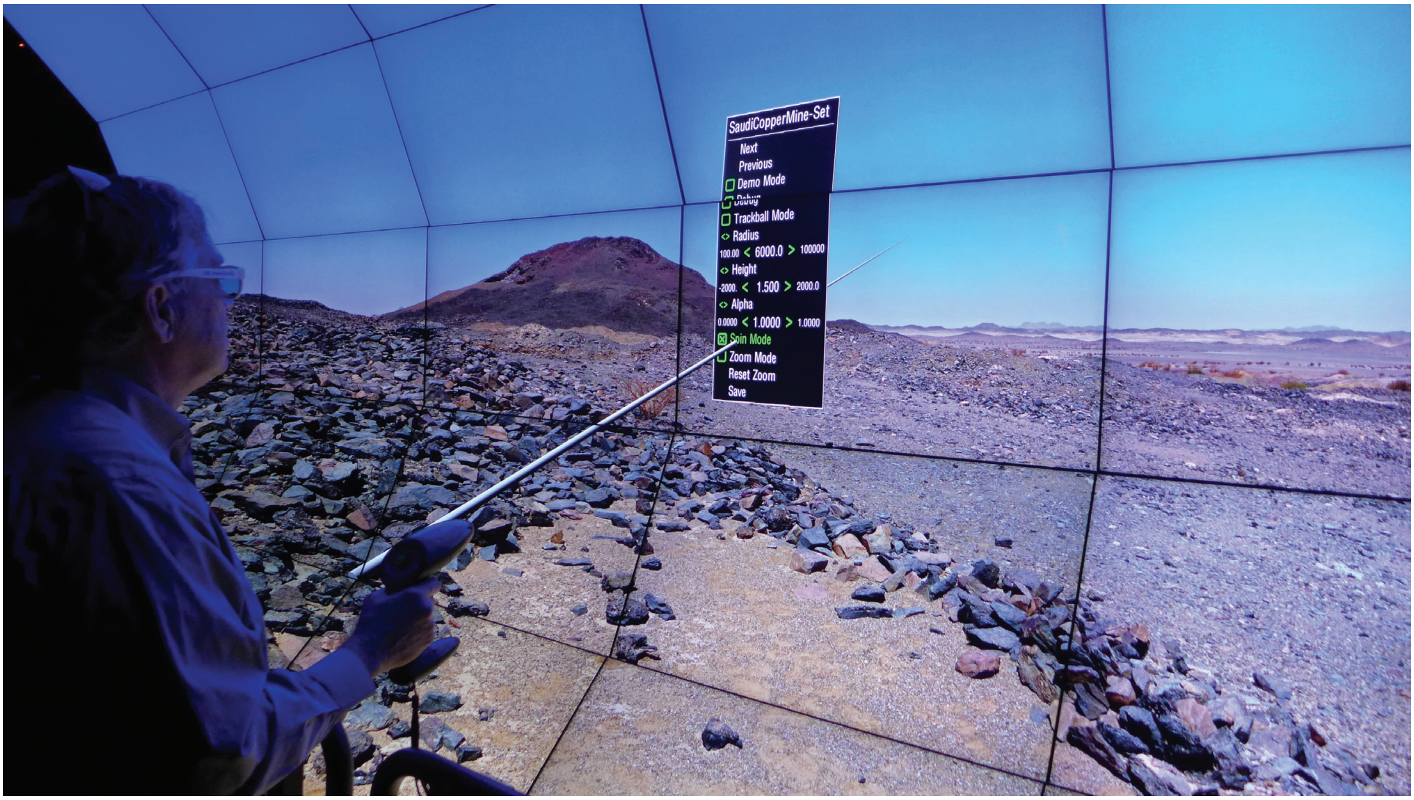


Figure 5. A copper mine in northwest Saudi Arabia viewed in the WAVE. This imagery was obtained with the CaveCam system. Photograph courtesy Qualcomm Institute, UCSD.

cial facet of this type of research: interdisciplinary collaboration. We can only be successful in pushing the boundaries of cyber-archaeological research by sharing our ideas and resources through partnerships like the one we have established here in San Diego. Furthermore, the costs have consistently been going down to the point of soon becoming a commodity. The Oculus Rift, a head-mounted VR device, is expected to enter the consumer market within less than a year's time, only slightly above the price of a computer monitor. VR input devices have already entered the consumer market, with the Razer Hydra, the Microsoft Kinect, and Leap Motion finger tracker and others, all well within the price range of other computer peripherals for the consumer market. We believe that the upcoming few years are going to make VR accessible to every computer user, including archaeologists, whether at home or in the field. This will open up an enormous realm of opportunities in the new discipline of cyber-archaeology.

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