The Age of Sensing
5th International Conference on Remote Sensing in Archaeology
In the past, the International Conference on Remote Sensing in Archaeology has been hosted in China, India, and Italy. For the first time in its history, the conference will take place in the United States at Duke University in Durham, North Carolina. The conference theme will be “The Age of Sensing.”

The 1990s will be remembered in the history of archaeology as the age of GIS. Now, we are ready to embrace new methods of recording, interpreting, conceptualizing and communicating archaeological data and relationships across the passage of time. In the next few years, we will have the opportunity to blend the physical world with a sensory-rich ‘virtual’ world where archaeologists can naturally and intuitively manipulate, navigate and remotely share interpretations and case studies. Our understanding of archaeology will be taken to a new level, enhancing our capacity to develop interpretations and to present them to fellow specialists and to the general public as simulated scenarios in 4D.

This conference seeks to explore the age of sensing, broadly defined. Papers and workshops will address the following topics:

- Close Range Sensing
- 3D Modeling
- Body sensing
- Immersive Sensing
- Aerial Photography
- GIS and Sensing
- Spatial Technologies and Landscape
- Virtual Landscapes
- Integrated Technologies
- Intra and inter-site Applications
- Lidar Applications
- Geophysics
- Sensing and Urban Context
- Cultural Resource Management
- Drones and UAV
- Remote Sensing
- Virtual Reality and Cyber-Archaeology
- Defining High Standards

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Integration of Multiproxy Landscape and Climate Data with Hyper- and Multi-Spectral Satellite Imagery for the Analysis of Landscape Change

William Middleton

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Hyperspectral Satellite Imagery (HSI) from the Hyperion Imaging Spectrometer aboard the Earth Observing One Satellite provides abundant spectral reflectance data over large areas. These data lend themselves to a wide variety of applications in the study of contemporary landscapes, ranging from the analysis of landscape diversity, the classification of reflectance spectra into archaeologically and biologically meaningful taxa, the extraction of abundance spectra for the identification of specific materials, to the calculation of spectral indices for the measurement of material properties. Over the past several years we have been using HSI as part of an interdisciplinary project that also includes Geoarchaeology, Paleobotany, Isotope Geochemistry, Ecology, and Archaeology in the study of the ecology of complex societies in Prehispanic Oaxaca, Mexico. Oaxaca has a deep history of human occupation, beginning with the Paleoindian period, that includes the rise and fall of one of the first state-level societies in ancient Mesoamerica, the Zapotec state (ca. 250 BC-AD 800). Throughout the Prehispanic past human behavior has both been shaped by, and has impacted the local environment. We present here two of the applications of HSI that we have developed as part of this project: the measurement of potential agricultural productivity of the prehispanic landscape, and the assessment of the impact of urban sprawl on cultural resources.

The Central Valleys of Oaxaca have a pronounced wet-season/dry-season cycle in
which most of the annual rainfall of 700 mm falls between May and September. As a result, most of the arable land away from the river flood plains can only be cultivated during the wet season. Using the Normalized Difference Water Index (NDWI), which measures water in plant tissue, we can compare dry season, during which there is sufficient water to support agriculture only along the river floodplains, and the dry season, when large areas of piedmont can support agriculture. The NDWI allows us to calculate the actual area over which agriculture can be supported throughout the year, and from that, estimate past potential agricultural productivity.

In the late 1970s and early 1980s, a full-coverage regional survey identified over 3,000 Prehispanic archaeological sites in the Central Valleys of Oaxaca. All of these sites were mapped on air photos, and their significant data recorded. In the three decades since the survey, the population of the Central Valleys, and Oaxaca city in particular, has skyrocketed and urban and industrial sprawl has impacted many archaeological sites. Using an ACE target detection algorithm, we are able to identify and measure areas of human habitation and construction in the contemporary landscape. We can then compare these images to digitized versions of the original survey air photos, and identify sites that have been impacted by urban sprawl and calculate the extent of the damage to cultural resources.

Remote Sensing Amerindian archaeology in the Caribbean Methods and Practice
Till Sonnemann; Douglas Comer; Bryce Davenport

Caribbean Archaeology can be separated in two main categories, pre- and (post-) colonial archaeology. The two types demand very different ways of analysis. For remote sensing purposes, the Amerindian pre-colonial landscape is particularly challenging. The indigenous people who settled in the Caribbean left little structural remains. Midden and ceramic accumulation are often the only evidence to identify occupation areas and settlements.

Over the last decade, groundbreaking work has been done regarding Native American heritage on the continent, showing the potential of multi- and hyper spectral analysis with a range of sensors of different wavelengths. A number of test cases are known for the Caribbean. For the current project, high resolution SAR and multispectral data has been acquired for a number of Caribbean regions and smaller islands of strongly varying natural environments, to identify Amerindian evidence through a direct detection method.

On the islands of the Lesser Antilles, traces of the Carib culture are difficult to find onsite, even less with remote sensing. Today, developable lands are either densely populated, particularly on coral based carbonates, or, in the case of the volcanic island arc, parallel to the west of the Puerto Rico trench, tropical forests remain on the volcanic
peaks in the center of the islands. This is why the study concentrates predominantly on the Greater Antilles, where the varying landscapes present more opportunities to identify archaeology, so as ball courts and large-scale settlement features. At particular locations, hilltops were transformed and flattened for the construction of wooden buildings; their footprints are identifiable.

The paper will discuss the variety of remote sensing techniques suitable to identify Amerindian evidence, with an intent to also better describe the looting currently occurring. The work is associated with the ERC-NEXUS1492 project, which investigates the impact of the European’s arrival on the Amerindian population and how this transformed the Caribbean landscape. The research leading to these results has received funding from the European Research Council under the European Union’s Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement n° 319209.

A clearer sense of self: landscape-scale remote sensing of human impacts during the Anthropocene

*Benjamin Vining; Tom Sever; Rob Griffin; William Saturno*

Recent attention has turned towards delimiting and defining the Anthropocene—a new geological period defined by pervasive anthropogenic controls over environmental processes on a global scale. The International Union of Geological Sciences is now determining whether an Anthropocene epoch will be formally recognized, and what temporal and stratigraphic markers will define it. Dates range from 8000 bp to the Industrial Era to the Nuclear Age, and cite evidence of early human influence over atmospheric composition, modification of soil and hydrological systems, and other anthropogenic changes with cumulative global impacts. Much of the ambiguity contributing to the Anthropocene debate centers on the visibility of prehistoric impacts, their magnitude, and the apparent exceptionalism of the modern period.

Archaeological remote sensing needs to enter this debate. Large-scale remote sensing programs increasingly demonstrate the profound, cumulative, and continued impacts of ancient anthropogenic activities on modern environments. Using examples from our work in the American neotropics, we discuss how remote sensing can help reconstruct a more complete picture of anthropogenic impacts on ecological functioning. We use high platform multispectral and SAR data, integrated with geospatial analysis. These approaches are essential in global regions where instrumental and historical records are very limited and where anthropogenic activities are not immediately apparent by modern standards. We demonstrate how past land use legacies continue to structure vegetation communities, hydrological networks, and anthropogenic soil regimes (anthrosols). Modeled reconstructions show the potential influence of these impacts on coupled earth-atmospheric energy systems, with regional and possibly global-scale implications. Paired with palaeoenvironmental and palaeoclimatic data, remote sensing archaeology reconstructs trends of anthropogenic environmental systems over broad regions.
These results expand our perception of past anthropogenic impacts, demonstrating their pervasiveness and persistence. Remote sensing thus contributes to a more robust sense of the Anthropocene, and ultimately a better sense of ourselves.

**Tracing the Traditional Water Systems known as Karez in Southern Afghanistan**

*Philip Stinson; Matt Naglak*

Phil Stinson of the University of Kansas and Matt Naglak of the University of Michigan propose to present results of three years of research (sponsored by the US Army Research Office) involving the large-scale mapping of the traditional water systems of Afghanistan known as karez (also known as qanat in Iran). A karez is a hand-dug, underground tunnel that taps groundwater and brings it to the surface using gravity. Karezes range in length from a few hundred meters to over 10 km. The cultural and geographical origin point of their technology is debated today but is traditionally thought to date back to the Achaemenid period or c. 500 BC. With Google Earth imagery, a GIS database (ESRI ArcGIS), and limited access to high-res imagery provided by the U.S. Army Corps of Engineers Geospatial Center, Stinson, Naglak, and a small team of graduate students in the Department of Classics at the University of Kansas have documented nearly 6,000 karezes and traces of karezes in southern Afghanistan. The team’s development of methods for assessing whether or not a karez is active using remotely gathered information offers improved documentation over previous studies whose quality has been compromised by the repetition of outdated data originating as far back as 1967-8, and by the impediments of doing large-scale mapping in a war-torn
landscape. These results represent the most comprehensive assessment of karez usage in this region of south central Asia to date and contribute to the global discourse on water resource sustainability and environmental security.

A Non-Destructive Remote Sensing Project Testing of Geoarchaeology Radar In South Texas
Rolando Silva; Russell Skowronek; Juan L. Gonzalez

Archaeological sites are precious non-renewable resources. Outside of Palo Alto Battlefield National Historical Park and the U.S.-Mexican War-related Fort Brown site little sustained archaeological work has been conducted in the Rio Grande Valley down-river of Falcon Lake. What other work has been done has largely been Phase I surveys, monitoring and salvage excavations. The proposed non-destructive remote sensing project at the Fort Brown Memorial Golf Course in Brownsville is part of a larger study of the potential of remote sensing for identification of subsurface features in the Rio Grande Valley and the promotion of geophysical techniques as preservation technologies for site surveying. The U.S.-Mexican War gun battery emplacement at the Fort Brown Memorial Golf Course was selected for two reasons. Fort Brown was minutely studied in 2011 using a variety of remote sensing techniques including historical documentation, aerial photography, magnetometer, soil resistivity (Ohm mapping), and ground penetrating radar. Thus, there is comparative data. The second reason is for boundary verification or expansion for the National Historic Landmark district. Contemporary nineteenth century maps indicate the presence of a battery south of the main fort during the U.S.-Mexican War. That battery no longer appears on maps dating from the Civil War and later. Did it exist and, if so, can it be identified. Within the Rio Grande Valley are geologic features known as deflation troughs. Aeolian carved, these features are the only known sources of water between the Nueces and Rio Grande rivers in Texas, filled by brushland desert covering an area over 150 km apart. Deflation troughs are bowl shaped depressions lined with impermeable soils, facilitating the passage of plants, animals, and people. It is hypothesized that dozens of archaeological sites lie within 4 km of the any location containing deflation troughs. We are currently surveying Hidalgo county, Texas using GIS images prepared in ArcGIS, and propose to utilize ground-penetrating radar to image the subsurface strata for comparative data correlating the historic to the geologic record.

Large Scale Geomagnetic Surveys in Archaeology
Rainer Komp

Cultural heritage management relies on observation and detection of historical monuments in order to establish their protection. Furthermore archaeology needs to
verify expected outcomes of fieldwork and focus on explicit research questions. Geomagnetic surveys have become a successful standard for such requested non-invasive explorations. Within last years research became more and more interested in landscape archaeology to broaden knowledge of single finds and phaenomena to get their whole contexts like rural surroundings and infrastructure of prominent palaces. Protection of cultural heritage in emerging nations as well as in crisis regions demand for fast registering of endangered monuments. As a respond to both geomagnetic surveys allow for quick and non-expensive exploration of huge areas up to 25 ha per day.

The German Archaeological Institute is steadily active in applying and developing systems for geomagnetic prospection within archaeological surveys. We are using multi sensor magnetometers for large-scale analysis; outstanding results have been reached with a frame combining 16 sensors on 4 m wide tracks assisted by a precise DGPS.

The talk will discuss our experiences and results in geomagnetic surveys on several places in Europe like e.g. Stonehenge in UK, settlements near the princely site of Vix in France, megalithic sites in Sweden or monuments in Bulgaria. We are building up a registry of analysed places and respective outcomes interlinked with gazetteers and bibliographies. Actual initiatives focus on the enhancement of more dense sensor data as well as computer-assisted analysis. Special attention is given to data standards for seamless postprocessing, long-term availability of data and linking with other data sources to knowledge networks. This is done by providing Linked Data. Another topic is the integration of multiple sensor data derived from additional sources like UAV providing low cost orthophotos, 3D-models or multispectral images in order to enhance recognition of hidden structures.

Close Range Sensing

Remote Sensing as a Method of Promoting Group Identity:
Rediscovering Edinburg’s African-American Cemetery
Rolando Silva; Juan L. Gonzalez; Russell K. Skowronek

Edinburg, Texas was founded in 1909 some fifteen miles north of the Rio Grande in the then newly irrigated “Magic Valley.” A decade later Hillcrest Memorial Park Cemetery was established. At the same time in a remote corner of the burial ground Restlawn Cemetery, as a racially segregated final resting place for African-Americans. According to records over the next 90 years around 50 people were buried in this area. Many of the earliest people interred hailed from rural households, and so due to a lower socio-economic status, some graves were unafforded lasting markers. And so, exacting numbers of inhumations are of course difficult to confirm without excavation. Over the years concerned citizens and the descendants of the deceased have taken it upon
themselves to help with grounds keeping at the cemetery, placing historic markers and new burials within its boundaries. Unfortunately, there are still a number of families that lay unaccounted for; there are men and women identified only by memorial homage to this day. To offer service towards this issue, in the Spring of 2013 a remote sensing survey using aerial infrared images and ground penetrating radar (GPR), to attempt to categorize the number of burials and their conditions in the rock record and environment, as part of a larger methodological study considering the utility of a variety of remote sensing applications for archaeological and geological research in the Rio Grande Valley. This fieldwork benefits from the support of the community and will shed light on a largely forgotten founding minority population.

3D Modeling

Reshaping Remote Sensing and Virtual Reality at Çatalhöyük

Maurizio Forte; Nicola Lercari; Emmanuel Shiferaw; Regis Kopper

Remote sensing data capture and virtual reality visualization have changed the archaeological documentation and interpretation of the Neolithic site of Çatalhöyük, located in the Konya province in Turkey (Berggren et al. forthcoming 2015). Indeed, since 2011, the ongoing excavation and digital documentation of the mud brick house Building 89 (B89) have produced a large amount of remote sensing data including representations of all the excavated stratigraphic layers as well as Ground Penetrating Radar prospections, and a number of digitized finds. Remarkably, ninety-eight high resolution 3D models of excavated layers have been generated so far via image-based modeling techniques—using an 18 megapixel Canon DSLR camera and Agisoft Photoscan—along with a similar number of colored point clouds recorded through a FARO Focus 3D shift-phase Terrestrial Laser. This unique dataset is a great resource for the interpretation of the material culture of Çatalhöyük as well as a great methodological challenge for virtual reality (VR) inquiry in archaeology. To provide viable solutions to this challenge, we designed and developed a scalable virtual reality application able to foster archaeological data analysis and interpretation in a realistic and highly interactive virtual environment deployable in an array of different systems. In fact, our VR application exploits the flexibility of a powerful game development ecosystem, such as Unity 3D, and enhances the perception and interaction with data via stereoscopic visualization, motion tracking techniques, and new commodity VR devices. Specifically, our application can be deployed as follows: desktop immersive VR based on a Z-Space interactive stereo display; portable VR based on Oculus Rift head-mounted display and Hydra Razer two-handed 3D controller; high-end immersive VR based on a six-channel CAVE—the Duke immersive Virtual Environment running on a PC cluster with high-end motion capture capability. In terms of data visualization, our application presents three different modes: micro scene visualizing the stratigraphy and finds of B89; reconstruction visualizing a hypothetic virtual reconstruction of B89 before
abandonment; *macro scene* visualizing the context of B89 via a Digital Elevation Model of Çatalhöyük East Mound and a number of excavated Neolithic buildings surrounding B89. The analysis of the archaeological data of B89 and nearby buildings is enhanced by database queries that can be executed directly within the virtual environment, making the 3D models a spatial interface to Çatalhöyük database. In addition, our application enhances the interpretation of B89 through custom VR tools as follows: in-context menus used to toggle different layers; in-context windows used to visualize photographs and drawings within the virtual environment; cross-section planes able to cut through layers; 3D annotation tools; volumetric visualization of each unit; graphics shaders that enhance texture, composition, and color of layers. The significance of our work relies on a cyber-approach to archaeology that integrates a plurality of data in a single simulation environment not limited by reality constraint where advanced interactive techniques simulates the depositional and post-depositional phases of B89 and its archaeological context.
Remembering and forgetting: the addition and subtraction of object context by using 3D printing.

*Peter Brugger*

An object exhibited in a museum will bring with it a narrative history,¹ this will go largely untold unless the museum conduct research and tease out this frequently reluctant history. Research and interpretation² are key to understanding. To look at archaeology, this enables the visitor to glimpse an often obscured world, to think about ancient societies or kingdoms that in the 21stC seem so alien.

This strength masks a weakness; magnified with the discipline of archaeology – the lack of context. Artefacts placed behind glass screens have been said to be purified³, this for the object suggests: clean, alone and free from anything that may be construed as clutter. For Archaeology displayed this should not be so, as when this is taken out of context we end up with an odd but interesting object in an alien environment.


Can the technology of 3D printing help? To produce 3D printed replicas of archaeological originals and then present them in a complimentary but very much secondary role; would this serve to benefit anything? The problem still would be context, as to 3D print a replica pot or Egyptian Ushabti Doll is to put the original to work and construct an object that is eroding context. We lose colour and weight, superficially all vestiges of realism\(^4\); but do we gain something — extra space to dream\(^5\) and discover? Interactivity assisting interpretation, education and furthering appreciation through haptics and not just sight, for archaeology this technology presents a set of exciting potentials.

With results based partly on original research\(^6\) we shall see how this technology can benefit the museum and expand upon the appreciation shown to archaeology.

DigUB: using 4D modeling to address archaeological questions in a prehistoric open-air archaeological site. 'Ubeidiya, Israel, as a case study

**Miriam Belmaker; Ashley Brown; Hale John; JC Diaz; Jeffrey Drouin; Benjamin Peters**

Paleoanthropology seeks to understand the variability in lithic assemblages as a reflection of the evolution of human cognition. In early cultures, such as the Acheulean, researchers suggested that a large part of the variability was due to the stochastic nature of the fossil record. A large Acheulean site is ‘Ubeidiya, Israel. This site is dated to 1.6 – 1.2 million years ago and rich in lithic remains. Stekelis has suggested that the older layers in ‘Ubeidiya were strictly of Developed Oldowan origin and devoid of handaxes and that younger layers, with handaxes, were Levantine Acheulean. In contrast, Goren suggested that the variability in lithic assemblages across strata did not reflect any cultural changes in ‘Ubeidiya and were probably related to depositional differences between high and low energy deposits.

Unique geological events that occurred ca. 500,000 years ago resulted in tilting of the archaeological strata as well as folding and some faulting. Thus, we hypothesize that the contentions within these two main research questions may be the results of a poor correlation between strata due to the post depositional folding and faulting. The inconclusive results may be the result of insufficient attention being paid to the effect of the unusual topographic warping.

\(^4\)H. Lipson and M. Kurman, 2013, *Fabricated: the new world of 3D printing, the promise and peril of a machine that can make (almost) anything*, (John Wiley and Sons, Inc)

\(^5\)G. Kavanagh, 2000, *Dream Spaces: Memory and Museum*, (Continuum)

\(^6\)P. M. Brugger, (February 2014), part one of data collection.
We suggest that by developing a 3D model of the site, using lidar scanning of the site itself combined with transform 2D contour maps, we will be able to digitally derive 3D models of the site. By using transformational computations and algorithms for palinspastic reconstruction of subsurface geology, we aim to produce heuristic models for points in time prior to the faulting of the 'Ubeidiya strata. This topological model will allow the user to digitally “correct” the strata and visualize them across a fully manipulable time-axis, allowing in effect to reverse geological warping over time, and thereby test hypotheses concerning the temporal and spatial correlations of the lithic assemblages within them.

This paper presents preliminary results from our model. The main novel theoretical contribution of this project is modeling the site along the dimension of time (4D). In particular, following the digitization process established by previous digital archaeological projects, 2D spatial data from the archives will be used in a 3D modeling analysis, providing a full spatial coordination of the site at any given time in the available nearly 400,000 year record. The 3D spatial schema will be synthesized across novel digital modeling techniques and theories to help unbend the strata folding that occurred during this period. This will allow us to test new hypotheses regarding the nature of the variability of the lithic assemblage of the site over time.
Aerial Photography

Pre- and proto-historic anthropogenic landscape modifications in Siem Reap province (Cambodia) as seen through satellite imagery.

Kasper Hanus; Emilia Smagur

Since the end of the civil war twenty years ago archaeologists in Cambodia have made a substantial progress in the research on the medieval landscape of the urban complex of Angkor. With modern technologies of archaeological prospection, Air-Sar and LiDAR, the researchers attempted to reconstruct the cultural landscape of the biggest low-density urban complex of the preindustrial world. However, on the regional level the sites are still identified after the colonial-era archaeological reconnaissance. Such state of affairs is unfavourable for two reasons: it hampers the understanding of settlement patterns in prehistory and history and impedes local heritage protection efforts taken against looting.

A current research project “Settlement patterns of NW Cambodia”, funded by the Ministry of Science and Higher Education of the Republic of Poland, aims to identify and map archaeological sites in four provinces of NW Cambodia: Banteay Meanchey, Oddar Meanchey, Siem Reap and Preah Vihear. This paper shall discuss the geomorphological features of the sites in western part of Siem Reap province visible in the satellite images. As Northwestern Cambodia is mainly an alluvial plain it is only natural for an occupied settlement to leave a recognizable mound of accumulated material. The inhabitants themselves occasionally dug one or more moats to circumvent the settlement. Such typical features of landscape are easily recognizable in satellite images, as well as from the ground level. Furthermore, the structure of past occupation can be deduced from the pattern of rice paddies, especially when it is radial, as contrasted with the modern pattern dominated by right angles.

Most of the features presented above are visible in the satellite images. This paper presents the general catalogue of geomorphological forms created by past societies that we identified and ground-truthed during the said research. What is also discussed is the problem of the so-called “false friends” – features like natural sinkholes that could be potentially misleading in further research. Information obtained during recognisance is stored in GIS database. The paper additionally presents an initial interpretation of the settlement pattern, derived from the correlative analysis of available resources and settlement location.

The Aerial Bombing of Pointe du Hoc, Normandy, France: A re-analysis based on contemporary aerial reconnaissance photography and field surveys.
Richard Burt

The storming of the medium coastal battery of Pointe du Hoc by elements of the 2nd Ranger Battalion under the command of James Earl Rudder is considered one of the most daring missions of D-Day. Most of the published literature on the subject correctly focuses on the heroism of the Rangers in storming and capturing a heavily defended coastal fortress. Accounts of the pre-invasion bombing include many inaccuracies and do not fully tell the story of how the bombing affected the ultimate outcome. The D-Day battlefield at Pointe du Hoc is one of the best-preserved battlefields of the Second World War. Many of the buildings and structures remain in a semi-ruinous state and provide tangible evidence of the damage inflicted by pre-invasion aerial bombardment and naval shelling. However the most easily identifiable effects of the bombing and shelling are the numerous craters that cover the site. Archival sources have identified seven separate bombing attacks launched against the medium coastal battery, the first of which was on April 25, 1944 and the final attack at H-Hour on D-Day. Aircraft from US Army Air Force and the Royal Air Force dropped bombs ranging from 200lbs up to 2000lbs. Analysis of intelligence reports and contemporary aerial reconnaissance photography indicate that the initial raid of the 25th April 1944 was accurate and many buildings were damaged and the accuracy of the raid and the realization that the battery had been identified led the German defenders to relocate the guns some distance inland. A re-analysis of the site sought to identify individual craters with individual air raids and bomb size in order to evaluate how the site was damaged in the months preceding the invasion. The position and magnitude of individual craters was determined using various surveying techniques such as: total station surveying, laser scanning and low-level aerial photography. Individual craters from the raids of April 25, 1944 and June 4, 1944 were identified by overlaying site drawings onto high-resolution aerial photographs and analyzed for proximity and contiguity. Individual craters from the raids between these two dates and immediately before the invasion were partially identified using statistical techniques.
The CRO Flies On: Locations and Landscapes in American History and Prehistory

Tommy Ike Hailey

In the spring of 2002, after considering a number of alternatives for acquiring aerial images, including UAVs and conventional aircraft, the Cultural Resource Office at Northwestern State University of Louisiana launched a research program to assess the suitability of the powered parachute as an archaeological aerial reconnaissance vehicle for site discovery, for detailed site investigation, and for cultural landscape studies. Since that time, this unique aerial platform has been successfully employed to acquire imagery of a wide variety of prehistoric and historical archaeological sites across the United States using a range of techniques, including digital still photography, digital videography, and thermal imaging. These images have been integrated successfully with aerial images from other sources, with historical maps, and with GPS, total station, geophysical, LIDAR, and 3-D laser scanning data by CRO staff members and by other researchers to provide a means of conducting detailed spatial analysis of archaeological sites and the landscapes in which they are located. This paper will present an overview of the equipment and the methodology, as well as various other considerations involved in using the powered parachute to acquire aerial images, including some of the legal issues, particularly as compared to the use of UAVs, which have been the subject of contention and controversy due to largely unwarranted negative publicity. The results from a number of case studies, including the Hopeton Earthworks (100 BC - AD 500) near Chillicothe, Ohio, and Alkali Station, Nebraska, a site that served as a Pony Express station and a U.S. Army post along the Overland Trail during the 1860s, will be presented. As indicated by these results, the powered parachute is capable of providing an extremely mobile, efficient, and cost-effective method for the acquisition of low-altitude, large-scale, high-resolution aerial images that has great potential in a wide range of archaeological applications.

Visualization of Archaeological Sites and Landscapes along the Missouri River Using Historical Aerial Photographs and Digital Photogrammetry

Adam Wiewel; Jesse Casana; Andrew Clark; Jackson Cothren

Due to the availability of low-cost software, digital cameras, and high-end computers, digital photogrammetry has become popular among archaeologists for a variety of purposes. One underutilized use of digital photogrammetry is for the production of orthophotographs and digital surface models of archaeological sites and landscapes using historical aerial photographs. This application may be particularly beneficial to archaeologists, especially in situations in which sites have been destroyed by development. Today reservoirs along the Missouri River in North and South Dakota
cover thousands of square kilometers of floodplains and lower terraces that were once inhabited, and their current shorelines continue to impact archaeological sites. As part of an ongoing collaborative project, thousands of historical aerial photographs dating to periods prior to and following the construction of five major dams and reservoirs along the Missouri River in the 1950s were acquired. We used AgiSoft’s PhotoScan to mosaic, orthorectify, and georeference landscape-scale aerial imagery and to produce high-resolution orthophotographs and elevation models. These orthophotographs permit us to visualize and map archaeological sites and features, some of which received only cursory attention by archaeologists prior to their inundation. Newly produced elevation models, greater in resolution than freely available elevation data for the Dakotas, enable us to reconstruct the Missouri River trench during various periods over the last 60 years.
Of the important purposes of Archaeology, is study of the interaction circumstances between communities each other and with ecosystem which living in, following up the cultural processes in the various eras in highlands with more than 2000 m. elevation from sea level, is a considerable subject field that ignored in the Archaeology of Iran. In the present research with utilization of environmental approach and using the Arc GIS program, on the basis of examining the geographical factors with respect to the settlement pattern of Sasanian era, we came to study that why and how Sasanian settlements in the Farsan county, as a region with such intermontane valleys and plain, formed and goes on, and determined that the most important factors in this process were accessibility to water and adequate pasture. Hereof locating in the close area with enough pasture for pastoral nomad communities, settling in the area with potentiality for irrigation agriculture for the settled people, and availability of communicating roads for both of these groups has a considerable role in the formation of settlement pattern of Sasanian Farsan.

In the continuation of the process that have been started in the Elymaean period, settlement pattern of this region in the Sasanian period, on the influence of the developed system of socio-politically control and probably state investment, which scheduled under Sasanian centralized power, shaped. So in this approach, the
connection between settlement pattern of sites and roads, as well as this point that the sites are not necessarily next to the riverbeds, make sense. In the Sasanian Period as precedent eras, habitation in mountain slopes and on the mounds beside the plain keeps on, these sites aside, we apparently saw that concentration of settlements moved in the central plain. In this Period, the size of sites is greater than precedent eras, which these are signs of population growth in this region in the Sasanian period. It seems likely that the growing of population in the Sasanian period is the consequence of vast exploitation of resources with habitation in the central plain and accessibility of more resources, utilization of strategic situation of Farsan region and communication roads, which nomads knows for a long time. Interaction between this region and other cultural zones, i.e. Khuzestan and Fars in the Sasanian period reflected in the archaeological data, e.g. form and decoration of pottery types. This similarity in the material culture matched with migration route of Bakhtiyari tribes.

**Identifying Use of Lands, Territories and Movements in Maya Signoury of Palenque, Chiapas; México**

*Guadalupe Zetina-Gutierrez; Rodrigo Liendo-Stuardo*

This paper is focused in show how remote sensing and GIS are helping to researchers to a better comprehension of rural landscapes in Maya Lowlands. Using a database of regional archaeological Survey Project of Universidad Nacional Autónoma de México inside of Signoury of Palenque, Chiapas in Southern of México and digital data (like satellite imagery) and GIS we are discovering potential economical uses of different niches and micro regions, exploring the relationship between patterns of use of agricultural lands, exploitation of other natural resources, paths and routes of transit using several tools of GIS. The implications of these patterns suggest it is possible archaeologists can understand better the phenomenon of rural population's movements in regional contexts through of them.

**Remote Archaeological Survey at Polygon of Protection of El Tajín, Veracruz, México**

*Guadalupe Zetina-Gutierrez*

The ancient sacred city of El Tajín is located on a cultural región known as Coast of Gulf near of the city of Papantla with 188 km north west of the port of Veracruz. Traditionally this area is known as the “Gulf Coast Zone” characterized by common elements such as “ball courts” spiral motifs representing movement, architecture with niches, and ancient rubber production.

Traditional full-coverage survey techniques cannot document ancient settlements and landscapes quickly enough to prevent destruction. LiDAR and other remote sensing
technologies are transforming the manner in which the way cultural patrimony is being recorded and manipulated. In El Tajín, I’m on charge of GIS and remote sensing to detect, record and verify on field ancient buildings and paths using orthophotogrammetry and Digital Elevation Model from LiDAR data on Zone of Archaeological Monuments of El Tajín at Veracruz State. In this sense, I really work with remote Archaeological Survey from my geospatial database enjoying advantages of a combination of high technologies contributing to research and conservation of archaeological remains in cultural region of El Tajín.

Testing predictive models for paleontological site location in the Eocene of Wyoming

Robert Anemone; Charles Emerson; Brett Nachman

Remote sensing and other tools and methods from the geographic information sciences (GIS) have the potential to revolutionize how fieldwork in vertebrate paleontology is conducted. In 2011 we trained an artificial neural network to analyze remotely sensed Landsat imagery and multiple GIS data and analytical layers in order to recognize different land cover classes, including productive localities, in Eocene deposits of the Great Divide Basin of SW Wyoming. Post hoc testing of the model indicated that it was able to recognize the spectral signatures of productive localities and other land cover classes with a high degree of accuracy (84% correctly classified pixels). Our predictive model was constrained by geology (limited to outcrops mapped as Wasatch formation), by topography (minimum required slope was 5%), and was limited to pixels that resembled known localities at the 98% probability level. During the 2012 field season, we surveyed two areas in the northern part of the Great Divide Basin that our predictive model suggested would have a high probability of being fossiliferous. Neither of these areas had ever been prospected or surveyed by our field crews in previous field seasons. The first area yielded no terrestrial mammals, but we did recover numerous characteristic Eocene vertebrate fossils (e.g., turtle, fish, crocodile, gastropod, bivalve) in deposits whose lithology (oil shales, limestones, and stromatolites) suggested a lacustrine origin. We confirmed that these deposits have been mistakenly mapped as
Wasatch formation and should be attributed to the Green River formation. In the second area, the exposed rocks were typical of the Wasatch formation (gray sandstones and mudstones). The area indicated by our model as having a high priority of being fossiliferous was in fact an extensive outcrop of heavily eroded sandstone that yielded typical Eocene terrestrial mammals, including *Hyracotherium* and *Hyopsodus*. We recently developed another predictive model based on an object-oriented analysis and supervised classification of high-resolution commercial imagery of the same deposits. Field testing of the predictions of this model in 2014 was extremely successful: we collected fossil vertebrates at 13 of the 31 survey points/polygons we visited whose spectral signature resembled that of a known, productive sandstone locality. A total of 25 new fossil-bearing localities were found in approximately 2 weeks of surveying using this predictive model, a much higher rate of success than would normally occur as a result of prospecting without the use of a predictive model. While the faunas collected from these new localities are not particularly rich or diverse, this work highlights the enormous potential that predictive modeling approaches hold for vertebrate paleontologists and paleoanthropologists.
As James Corner noted, “mapping is a fantastic cultural project, creating and building the world as much as measuring it and describing it.” Current technologies of remote sensing, GIS, and visualization provide greater detail, accuracy, and accessibility in the work of archaeological mapping than have ever been possible. A consequence of this level of precision can be the false sense that we can strip away the judgment and imprecision of human investigators and the historical context of their investigations. Do data so abundant and complete make our work more inductive than deductive? In practice, do we believe that there is some asymptotic limit at which our abilities to measure, map, and visualize will allow us to experience and analyze a past reality relieved of current encumbrances? What does it mean for our research when so much of the data we use – from satellite images to topographic maps – are generated by
researchers with other agendas (i.e. do the data speak for themselves)? What ideas guide the questions we ask, the methods we choose, and the criteria we use to evaluate our findings? These questions remind us how, at the same time that we continue to strive to improve our technological capacities and capabilities, we need to remain cognizant of what we are missing, forgetting, or obscuring.

With these questions in mind, this paper looks at the historical progression of understandings of the natural and settled environments of the Basin of Mexico over the past 3,500 years. The focus is on the mapping and visualization of a dynamic feature of the landscape – lakes that rose and fell with the seasons and that have played a critical role in the human occupation of the basin. These lakes have been all but completely drained over the past several hundred years, but their boundaries can and have been reconstructed through different methods over time. Each of these methods and sources reflects a different agenda and historical moment – the present notwithstanding. Data sources include historical maps, archaeological settlement pattern surveys, paleoenvironmental studies, historical air photos, and contemporary technologies of remote sensing. Our goal is to frame our current technologies as no more ‘true’ than past understandings and to consider them in the framework of our particular historical moment. By layering together the multiple understandings, looking for gaps and inconsistencies, and treating contemporary data as one of many sources of understanding the physical and political past of the Basin of Mexico, we may achieve an even more satisfying appreciation for the history of this landscape.

3D-GIS in Pompeii: an exploratory approach to the study of insula V 1

Nicolo Dell'Unto; Giacomo Landeschi

The Swedish Pompeii Project was started in 2000 by the Swedish Institute in Rome as a research and fieldwork activity. The aim was to record and analyze an entire Pompeian city block, Insula V 1. Since autumn 2011 a new branch of advanced digital archaeology, involving 3D reconstructions and documentation methods, was added to the project agenda. In the frame of this new acquisition activity the insula was completely digitized by means of laser scanner technology and image based 3D reconstruction techniques. The results of this acquisition were used to develop different research activities in the area of digital visualization.

In the frame of this work, a new methodological approach was setup with the purpose of implementing the above-mentioned dataset into a 3D-GIS platform. The system allowed managing and visualizing the 3D models obtained after the acquisition campaign in relation with the different archaeological information previously imported and stored. Once implemented the system allowed (i) testing a completely new documentation approach to be used for analyzing the ancient structures, (ii) defining a database scheme for managing metadata information and estimating the degradation level of the architectonic decorations of the insula, (iii) and studying the relations between the private and public space of the insula using visibility analysis tools. Aim of
the present paper is to generate new insights into the use of GIS as a tool for investigating the ancient buildings and discussing the social significance of space in Roman society.

Graeco-Roman Astro-Architecture?: The Temples of Pompeii

Vance Tiede

Classics literature documents that astrology and astronomy played integral roles in ancient Greek and Roman religion (e.g., Cumot 1912; North 1990; Jones 1994). However, surviving historical texts contain gaps regarding temple orientation that GIS and astro-archaeology might be able to fill. For example, although Roman architect Marcus Vetruius Pollio (ca. 75-15 BC) wrote that, “The quarter toward which temples of the immortal gods ought to face is to be determined on the principle that…the temple…should face western quarter of the sky.” (Vitruvius, IV:5,1), his astro-architectural principle was largely ignored even in Rome (e.g., the Pantheon faces north), let alone at east facing Hellenistic temples throughout the Empire (Oudet 1992; Hannah & Magli 2011; Boutsikas 2008-2009; Nell 2013).

In order to shed more light on the hypothetical role of astronomy in temple orientation, the author surveyed 11 temples at Pompeii, Campania, Italy (N 40d 45’, E 14d 29’) attended by Oscans, Phoenicians, Etruscans, Samnites, Egyptians, Greeks and Romans ca. 500 BC - 79 AD, viz.: Doric, Dionysus, Ceres, Venus, Apollo, Aesculapius (Zeus Meilichios), Jupiter (Capitolium), Isis, (Caesar Augustus &) Vespasian, Sanctuary
of the Public Lares, and Fortuna Augusta. A preliminary GIS/DEM/Remote Sensing survey measured the true azimuth and horizon altitude of each temple’s major axis. The preliminary data was “Ground Truthed” by field survey with theodolite and GPS, 5-18 April 2013. The resulting 3D vector survey data was analyzed with Program STONEHENGE (Hawkins 1983, 328) and Starry Night Pro Plus 6 planetarium software in order to identify major axes aligning with culturally significant astro-target declinations on the local horizon in antiquity.

All 11 temples appear to be oriented to astronomical targets on the local horizon mentioned in classics literature or agricultural calendars, viz.: α Boötes-Arcturus Equinox heliacal rise; Midwinter Moonrise Major Stand Still; Equinox Sunset; β Orionis-Rigel Summer Solstice heliacal rise, February/November Cross-Quarter Day Sunsets; Winter Solstice Sunset; Midsummer Moonset Major Stand Still; and θ Scorpionis-Sargas Winter Solstice heliacal rise. Analysis also suggests that the major axes of four temples may not only be oriented astronomically, but also parallel to Pompeii’s urban grid (Le Bœuffle 1989, 106) oriented N-S cardo (Porta Vesuvio - P. Stabia) on Mt. Vesuvius’ slopes to optimize urban sewer/street drainage (Hodge 1992) and E-W decumanus (P. Sarna - P. Marina) oriented to optimize seasonal sunlight/shadow (Vetruvius, I:1,4).

Spatial Technologies and Landscape

A LONG WALK IN THE ITALIAN COUNTRYSIDE: Large-scale geophysical prospection in rural and urban contexts in central Italy

Stefano Campana; Ken Saito; Barbara Frezza

Geophysical prospection has long been recognized as one of the most effective forms of non-destructive archaeological investigation. In Italy, however, it has yet to be applied widely by archaeologists – or demonstrated publicly through successful case studies – as an effective tool at other than individual-site level. Certainly its potential for large-scale characterization of threatened archaeological contexts, and of previously unexplored rural and urban areas, has remained largely unacknowledged or tested in the field. This contribution, however, will present the first results of a programme of large-scale multi-sensor magnetometry that has covered the whole of the Etruscan and Roman town of Veii, near Rome, as well as initial exploration of the rural landscape of the Grosseto-Roselle valley in Tuscany. The research project aims at stimulating changes in the way in which archaeologists in Italy study the archaeology of landscapes, moving from an essentially site-based approach to a truly landscape-scale perspective. This kind of investigation, especially if combined with field-walking survey and aerial prospection, along with lidar imaging and test excavation wherever possible, could create an entirely new context for the exploration of previously unconsidered rural
as well urban contexts in Italy and perhaps more broadly throughout the Mediterranean area.

**A Dynamic Study of Multi-scale Space Monitoring on the Great Wall and Surrounding Environment**

*Chuansheng Liu; Xinyuan Wang*

Drawing on the international experience in successful applications of spatial information technology in cultural heritage, the project selects a typical section of the Great Wall, a World Heritage Site, as the demonstration area, applies spatial information technologies such as remote sensing (RS), geographic information systems (GIS) and global positioning system (GPS), and integrates with the research results of archaeology, philology, history of science and other disciplines to provide research basis and application reference for the management, monitoring and demonstration of the world heritage. The study on the Great Wall gives full play to the unique role of spatial information technology in world cultural heritage research, conservation and management, highlights the spatial cognition of world cultural heritage, and promotes coordinated and sustainable development of the relationship between the heritage sites and the environment. By integrating remote sensing monitoring and research results of the Great Wall with archaeological and philological research achievements, it is possible to construct a framework for applying spatial information technology to monitoring and
protecting the Great Wall so as to provide spatial technical support for the management, monitoring and display of the Great Wall.

**Viewshed Analysis at Multiple Scales: GIS Methods on the Medieval Iberian Frontier Landscape and 3D Intervisibility at a Reconstructed Fortress-Monastery**

*Edward Triplett*

The concept of intervisibility is a familiar tool for archaeologists and historians seeking to deduce the intentions of builders in their choice of site. For the subjects of my dissertation – the Christian military-religious orders who occupied the shifting Iberian frontier with Islam during the 12th-14th centuries – intervisibility meant increased security and the projection of power by a minority over a combative majority on one hand, and the importance of specialized architectural spaces on the other. This talk will discuss two methods of viewshed analysis that have informed the digital research of my dissertation. The first will focus on how GIS viewshed analysis tools help to extract meaning for military orders who occasionally built – but typically occupied – hundreds of hilltop fortresses overlooking contested frontier landscapes during the Christian reconquest of Muslim-controlled Iberia. The inter-site analysis of military order architecture will demonstrate how the natural landscape helped determine which fortresses became central to the reconquest effort, and which fortresses were relegated to minor status after their religious affiliation changed. The scattered loss and gain of key viewsheds / castles will be used to show how control over frontier zones fluctuated over time, rather than existing as the ever-southward constant illustrated by many historical maps of the Iberian reconquest.

The second project harnesses tools within Autodesk’s 3D Studio Max to perform an intra-site viewshed analysis of one military-monastic complex with a composite community of monks, military brothers and laborers. This project began with an attempt to capture dense surface data of the largely ruined fortress-monastery headquarters of the order of Montesa using kite and pole-aerial photogrammetry. After using this data as the foundation for a simple reconstruction of downed walls, the next goal was to derive 3D viewshed data of various spaces within the complex site. This research is designed to contemplate the extent to which the architects were concerned with partitioning the
composite community into separate, ritualized spaces while acknowledging the practicalities of an irregular, hilltop site on the frontier. Thus, at Montesa, we can look into the seemingly contradictory interests of a community that was greatly concerned with looking out away from the fortress toward a potentially hostile landscape below them, while also creating a cloistered central area designed to facilitate inward reflection and eliminate distractions from the “outside” world. Finally, this portion will discuss how the “light-meter” planes in 3D Studio Max can be appropriated to capture a form of 3d viewshed data when placed in intervals within a 3d architectural model.

Archaeology in the Age of Supercomputing
Devin White

As a discipline, archaeology is poised to fully embrace both the power and the peril of big data analysis. Our datasets are growing ever larger, especially those generated via remote sensing activities, as is the computational complexity of algorithms designed to exploit them. Analyses are quickly outpacing what can be done using a single processing core on a desktop computer, leveraging off-the-shelf commercial and open source software. Our research needs are becoming increasingly sophisticated, to the point where relying wholly on outside experts in computer science and related fields is untenable. While the above statements could be viewed as challenges, it is better to think of them as opportunities for archaeology to grow technologically and retain more ownership of some of our hardest problems.

This presentation will highlight several recent and ongoing efforts in the area of archaeological high performance computing, discuss the underlying technologies involved, and recommend how members of the audience can learn more about them and integrate them into their own research workflows. The case studies will include, but will not be limited to, large-scale versions of movement modeling, total viewsheds, bare earth model extraction and visualization, agent-based modeling, and social network analysis.
Archeology takes into account the physical artefacts which the history has left behind. The artefacts belong to a particular landscape and landscape evolves with time. Because of this, whenever we locate/ identify any artefact at a completely unexpected location in the study-area, we must account the fact that in context to it's history, the artefact is probably at the right or obvious location. In our current research we realised that collecting such data for spatial analysis and Ethnographic and Ethno-historic study of the site are very much complementary to each other.
The ancient site and temple complex at Chandhore (18°09'52"N; 73°11'02"S) (northern portion of the Western Ghats) was discovered in 2011 and then subsequently excavated (2012, 2013) by a joint team of members from the Centre for Extra-Mural Studies (CEMS), University of Mumbai and the India Study Centre (INSTUCEN) Trust, Mumbai. The excavations resulted in the discovery of a Shilahara Period occupation (AD1100) that in all probability continued through the subsequent Bahmani, Adilshahi and Maratha Periods (AD1500 – AD1800).

The excavations have to date exposed two temple complexes made up of temple plinths and a rock-cut Step-tank (within whose niche was discovered an in-situ icon dateable to the Shilahara-Yadava Period ie the 12th-13th c AD). Discoveries of a Gadhaiya coin, Monochrome Glazed Ware, typical Bahmani Glass bangle fragments and a number of microliths and stone tool making debris has forced us to study the complete temporal cross-section of the site. A series of laminated gravels have been discovered in the bed of the only channel that drains the bowl-like landscape of Chandore. We hope here to discover clearer evidence of the prehistoric past of the landscape. Along with these prominent discoveries, the team has come across various sculptural and structural members in stone. Two elaborate Hero-stones and another stele like element consisting of a cow suckling a calf have been discovered in number of instances at the site and in the surroundings. Some of these show an exceedingly fine level of craftsmanship whilst others are surprisingly crude, they are also unfortunately devoid of inscriptions. These stelae/pillars have been named Gaay-vaasru (Cow-Calf) pillars.

These Gaay-vaasru pillars appear to be in completely random locations such as backyard of a house, abandoned hillslope, roadside pavements etc. However when we tried to map the locations of these and correlate to the overall geography, a new picture began to emerge. The locational significance soon became obvious in many cases. The subsequent question was whether there was any significance due to specific sculptural details e.g. Sun and moon on different sides and their orientation (do they relate to east/west?), the cow's head in different directions (does it indicate road direction/ a boundary?), the slabs facing different directions (do they demarcate a boundary for anything?). Many of these slabs seem to follow the 200m contour with some variation. Understanding of such different aspects of these elements using spatial techniques and then fitting them in the historic landscape/ time with other discoveries are our current crucial objectives.

The Simbolic Landscape of Archaeological Zone of El Tajín, Veracruz; México

Patricia Castillo

La aplicación de los tres sensores remotos como LiDAR, Otofotogrametria y la Termografía nos ha proporcionado una nueva visión de la zona arqueológica de El
Tajín. La aplicación de esta nueva tecnología nos ha permitido hacer una nueva interpretación del antiguo asentamiento, sin tomar en cuenta los aspectos urbanísticos sino sus ejes paisajísticos. En donde los más importante es su horizonte inmediato, así se pudo descubrir que el Cerro de los Mantenimientos, es dentro de la Cosmovisión y dentro de la orientación, el eje principal. En el año de 2013 se hizo el descubrimiento de un evento lumínico y en el 2014 se confirmó la importancia simbólica del sitio y del edificio de los Nichos a través de la manifestación de Luz en lo que hemos denominado “Los Cuartos de Año”.

Application of three remote sensing like LiDAR, orthophotogrammetry and thermography allow us to obtain a new perspective of archaeological zone of El Tajín, Located on cultural region known as “Cost of Gulf” in Veracruz State, México. Our study is actually occupied by moderns Totonacs. The uses of these new technologies help us to do a new re-interpretation of the ancient settlement taking in account, not urbanistic aspects instead landscape axes. In this new approach, we discover the "Support Hill" (Cerro de los Mantenimientos) as a main axe and center of cosmovision of Totonac people. During equinox of 2013, it was discovered a event of descent of light over the main and the most unique building of El Tajín: Niche's Piramid (Pirámide de los Nichos) and during this year was confirmed the simbolic importance of the ancient sacred city and the Niche's Building through of archaeo-astronomic event called: "Los cuartos de Año" (year's quarter).
This paper presents (1) a synopsis of 3D tools for vegetation modeling and landscape visualization, (2) evaluates the pros and cons of these tools, and (3) then builds on these findings to propose a workflow to integrate archaeological, paleoenvironmental, and ethnobotanical into a GIS for export into a virtual landscape for investigations of ancient socio-environmental interaction. Using this workflow and a case study at the UNESCO World Heritage Site of Copan, Honduras, our long-term goal is to develop an open source database that houses various data useful for reconstructing ancient plant communities in Mesoamerica and a digital tool that allows users to integrate georeferenced 3D plant models and 3D architectural models into a virtual landscape to explore changes in landuse and settlement patterns by changing parameters for a set of predefined models. Ultimately, we seek to develop innovative and interactive ways for students, scholars, and the public to explore and understand socio-environmental interaction.

To achieve this objective, we begin with the following questions:

1. What approaches do biologists, ecologists, etc. use to simulate plant habitats in landscapes? What types of data do they use? How do they use them?
2. Which of these approaches can we use given our dataset, e.g., palynological, hydrological, soil, geology, and ethnobotanical? What methods can we not use? What other data might we need?

Some possible approaches include: (1) Use of pollen data from soil cores to estimate the proportion of different plant species and functional groups within the region, (2) Ordination analysis of current plant communities to determine what habitats different communities are most likely to occur in, (3) Use of modern data and soil cores to estimate paleohabitat characteristics such as soil type, elevation, and precipitation, and (4) Integration of these three data sets in a GIS to model potential plant distributions. The implementation of these approaches will require further collection of data on current plant communities, and possibly further assessment of paleosoils and microclimates.

To visualize resultant plant distribution models in a 3D georeferenced landscape, we have investigated currently available software and plant libraries, and have found that they generally lack the interoperability, iterations, and plant species we hope to include in our project. Thus, we have begun to explore a workflow that integrates alternative and open source methods for building 3D simulations of the desired plants and ecosystems. We are leaning toward a procedural modeling approach, which will allow us to model plants using rule-based procedures, in a georeferenced framework, and afford us flexibility for iterative visualizations, and allow us to produce visual communities of unique plants that are both more visually appealing and more realistic.

Our research is affiliated with the MayaArch3D Project (www.mayaarch3d.org) – a Digital Humanities project linking GIS and 3D technologies for research on ancient architecture and landscapes.

The ancient salt marsh landscape of the Venice lagoon

*Sophia Sennett; Sonia Silvestri*

A coastal lagoon is a highly dynamic environment characterized by a number of processes that continuously change its shape and morphology. The Venice lagoon is the most significant example of these dynamics, as the natural changes overlapped and intertwined with the anthropogenic actions, producing over the centuries a unique and fascinating environment. The Venice lagoon is, and has been in the past, the cradle of history and cultural heritage, natural and built environment, source of life and food. Through the use of historical maps and the development of a model of the salt marsh morphological evolution, we simulate the virtual landscape of the ancient Venice lagoon, when it was extremely rich of salt marshes and tidal creeks. The virtual reality thus created will allow us to "visit" the old lagoon system within the 3D visualization system called DiVE.
The use of multispectral satellite imagery and LiDAR in archaeological applications from site prospection to landscape analysis has been growing rapidly in recent years, but there has been little research done on how the two approaches might work together to create more robust archaeological remote sensing methodologies. This paper aims to address that question by comparing the results from analyses of high resolution multispectral satellite imagery conducted with the goal of identifying potential archaeological features to the results from LiDAR data collected in the same area for the same purpose. The case study region is located in eastern Honduras where very little archaeological research has been conducted, an area of rugged terrain and dense jungle. As such, the multispectral data analysis employed an indirect approach to find potential archaeological features based on identifying variations in the forest canopy that can be indicative of underlying archaeology. The locations of potential features detected by this method were then compared to LiDAR data of the same area but with the vegetation cover digitally removed to reveal the ground surface and any potential archaeological features evident as anomalous variations in the topography. It is found that while both approaches to site prospection did identify anomalies in the same locations and which can be interpreted as potential archaeological features, there are other anomalies that one method detected but the other did not, and vice versa. Possible reasons for these different results will be explored with the goal of providing
the archaeological community with a better understanding of the strengths and weaknesses of each approach as well as how these two different remote sensing applications might be used together to improve efficiency and accuracy in archaeological site detection.

The Computational Research on the Ancient Near East (CRANE) Project: Large-scale Data Integration, Analysis, and Modeling in the Orontes Watershed

Stephen Batiuk

The Computational Research on the Ancient Near East (CRANE) Project is an interdisciplinary collaboration undertaking the integration and analysis of data from a number of archaeological projects working within and beyond the Orontes Watershed of the Northern Levant within a single computational framework. The aim is to facilitate the analysis, modeling and visualization of the interrelationships between social, economic, and environmental dynamics at various spatial and temporal scales in order to address questions about the rise and development of complex societies in this important region.

The initial stage of the project has involved the integration of data from two ongoing projects in southeastern Turkey (the University of Toronto’s Tayinat Archaeological Project and the University of Chicago’s Neubauer Expedition to Zinçirli Höyük), and one in northern Syria (Laval University’s Tell Acharneh Expedition), and will begin integrating data from two additional sites in Syria: Tell Nebi Mend (Universities of Durham and Sydney) and Tell Mishrifeh (Università degli Studi di Udine). These sites share similar occupation sequences spanning the Bronze and Iron Ages. In this paper I outline the objectives of the CRANE Project, discuss the integration of these rich datasets using the University of Chicago’s Online Cultural and Historical Research Environment (OCHRE), and introduce and assess some preliminary results of our corollary sub-projects, including projects focusing on 3D Visualization and shape matching of ceramics, before discussing the CRANE Project’s future directions.

Terrestrial Laser Scanning at Catalhöyük: New Methodologies, Results, and Research Perspectives

Nicola Lercari

The multimodal documentation process of the Neolithic site of Çatalhöyük, located in the Konya province in Turkey, relies on the integration of an array of cutting-edge survey technologies such as LiDAR, Terrestrial Laser Scanning (TLS), Ground Penetrating Radar (GPR), and Image-based modeling. TLS survey underpins the digital
recording process of Çatalhöyük East Mound both at macro-scale and micro-scale levels. Since 2009, multiple laser scanners have been employed for the documentation of every stratigraphic layer of the excavation of the Neolithic house Building 89 (B89), for the digitization of finds such as figurines, pottery, stone and bone tools, as well as for area-wide documentation of North, South, and TPC areas for conservation evaluation. Starting in the excavation season 2011, TLS survey has been implemented using a Faro Focus 3D Shift Phase laser scanner, capable of maximum precision of 2mm on 80m distance. Given the high number of stratigraphic layers to be recorded and the vastness of the areas to be surveyed, a scan quality of ⅛ and a resolution of ¼ were employed to generate accurate, RGB colored, point clouds with a resolution of about 5500 x 4000 pixels and about 11 million points per scan. To value the high volume and precision of recorded laser scanning data, one needs to reflect on how TLS can benefit the documentation and interpretation process at Çatalhöyük. For example, how can micro-differences visible in scanned excavated layers and micro-topography analysis change the interpretation of B89? Can the decay process of Çatalhöyük mud brick houses be better stabilized using software-driven analysis of TLS data recorded in subsequent excavation seasons? Can the mapping process of excavated areas and the drawing operations of sections, walls, and features be improved and expedited by the employment of semi-automated feature extraction techniques performed on TLS data? Striving to find viable answers to such research questions, this work proposes a new workflow based on semi-automated post-processing techniques and the integration of multimodal data in a Geographical Information System (GIS) in order to formalize new horizons for digital archaeology and heritage conservation.
Getting closer to Iron Age through Remote Sensing: investigations in eastern Austrian pre-alpine landscapes

Martin Fera

The implementation of Remote Sensing methods in archaeological research has gained momentum by a fast development of methods and tools and a broad availability of various data sets in recent years. Their benefit for the detection and examination of archaeological sites on different scale levels has been proven in many areas around the globe. This paper presents strategies for the integration of remote sensing tools in cultural historical research.

The pre-alpine area of eastern Austria has been in the focus of a number of projects utilising Aerial Archaeology (AA) and Airborne Laser Scanning (ALS) to investigate large areas systematically. The methods supplemented by targeted pedestrian survey, proved to be perfectly complementary to investigate both, parts of the landscape under agricultural use and forested areas.

A lot of methodological development was done to bring the data to its best use by applying different processing steps on multiple scales. Different filtering and visualisation methods were compared and refined for interpretation of surface structures, while ways of investigating and interpreting the data sets in a three-dimensional (3D) environment were explored.

While the results of the aforementioned projects incorporated archaeological structures and remains from various prehistoric and historic periods this research focuses on the first millennium BC, investigating a diachronic development of Iron Age land use and settlement structures. In Early Iron Age (EIA) hilltop settlements are the prevalent type with associated barrows. Some lowland settlements are known and documented. A change in settlement pattern can be noticed during Late Iron Age (LIA) where from 5th to 3rd century mainly lowland areas where occupied. Settlements are characterised as dispersed farmyards and disclosed villages. This picture changes in 2nd century with the advent of regional proto-urbanised fortified sites.
Combining systematic AA and ALS yielded good results in the identification of settlement and funerary sites and contributed significantly to the data basis for further spatial analysis and interpretations. By the investigation of DEMs in 3D previously unknown hilltop settlements have been identified and the quantity of funeral places could be doubled by identifying barrows both as standing structures in forested areas and as crop marks in aerial pictures. For LIA an extensive lowland settlement area could be mapped from aerial images. The interpretation of the visible structures on site scale and the collection of surface finds indicate an extensive occupation phase at the beginning of LIA.

For intra-site analysis of a LIA fortified settlement geophysical surveys and targeted excavations have been carried out. A large part of the inner structure was geophysically surveyed and parts where excavated. During the stratigraphic excavations the use of terrestrial 3D-laserscanners and image based modelling techniques proved to be a valuable addition to the documentation process.

Documenting the past: the use of digital technologies for intra-site archaeological documentation

Nicoló Dell’Unto

The diffusion of digital technologies has strongly affected the way scholars and researchers use and perceive the archaeological information detected during the field investigation process. Nowadays digital instruments are used in archaeology at any level, and their employment increases the possibilities to document and visualize, with high accuracy of details, the information detected during the investigation campaign. In particular, in the frame of the excavation practice, the development of powerful visualisation platforms, such as the Geographic Information System (GIS), and the introduction of digital acquisition tools, e.g. Total Station, Laser Scanners and Image Based 3D modelling Techniques, have procured the opportunity to fully visualize and study in three dimensions (3D) the spatial and temporal relations between the strata detected during the site investigation.

The combination of different technologies and the construction of more and more functional workflows of data acquisition allow defining new solutions to manage and analyse large three-dimensional data set of archaeological information. In specific, the possibility to produce and visualize texturized 3D models in the time frame of the excavation, opens to new opportunities to use the data to plan or review, in real-time, the investigation strategy adopted in the field. These methods allow for visualization systems capable to simulate and reconstruct in three dimensions the sequence of actions performed by the archaeologists to investigate the site. In this paper, the results of several experiments performed during different field activities are presented. In
specific, the different approaches adopted to visualize and study in three dimensions the on-going investigation process are compared and discussed.

**Terrestrial Laser Scanning and Unmanned Aerial Systems to Investigate Historical Rice Cultivation at Wormsloe Historic Site**

*Alessandro Pasqua*

Despite much of the environmental history of Wormsloe Historic Site on the Isle of Hope, Georgia having previously been documented and described, there are still some aspects that require deeper investigation. For example, whether rice cultivation was ever performed at Wormsloe is a question that does not have a definitive answer. The primary goal of this study, therefore, is the investigation of the Isle of Hope landscape through remote sensing techniques such as terrestrial laser scanning (TLS) and unmanned aerial systems (UAS) to identify archaeological evidence related to rice cultivation. Terrestrial laser scanning will be employed to create an accurate and high resolution 3D bare earth digital elevation model (DEM) of the areas under investigation in order to analyze present-day microtopographic features that may correspond to features indicative of old rice fields such as ditches, canals, and embankments. Furthermore, the use of UASs will provide a detailed aerial view of the study area that can be used to generate a geovisualization of the landscape. The collection of multiple images of the terrain from different angles will allow the employment of an emerging technique in photogrammetry known as Structure from Motion (SfM) to create 3D models of landscape features. Evidence related to historical rice cultivation at Wormsloe would greatly enhance the archaeological and historical significance of the property, and would provide cultural resource managers with archaeological evidence related to Georgia history that should be preserved for generations to come.
From Data to Experience: Integrating Multiple Datasets to Create an Immersive Representation of Ancient Tiwanaku

James Wesolowski

A UNESCO World Heritage Site and the seat of a major pre-Incan polity in modern Bolivia, Tiwanaku was home to tens of thousands of people and is thought to have been a religious destination for many more. Although relatively understudied, with early work focusing on the monumental core of the city, the last few decades have seen great progress in researching residential areas surrounding the core and providing a better understanding of how the city and its people functioned, both internally and as part of a larger regional system. One question recently receiving attention is the meaning of the transformation in the built environment around 800 CE, where the destruction of domestic structures made way for new monumental architecture, possibly reflecting a change in the expression of political power and the relationships between commoners and elites as well as citizens and visitors.

Over the last 12 years, substantial amounts of digital data have been acquired from Tiwanaku that facilitate a 3D approach to studying its built environment. GPR surveys conducted between 2002 and 2006 have produced approximately 10 hectares of data in residential areas of the city. This is complemented by magnetometry, resistance, and electromagnetic induction surveys in a subset of this region. In addition, terrestrial LiDAR survey was conducted of the entire monumental core in 2005-2006. The current project interprets and combines the geophysical and LiDAR data with other sources, including excavation reports, historical aerial photography, and ethnographic studies, to create an integrated model of the city with both monumental and domestic architecture. This 3D model will then be placed into a modern game engine that will be used to experience the built environment before and after this change. The first-person perspective will provide a new approach to studying Tiwanaku and its phenomenology as well as offer a powerful way to better understand how differences in architecture and urban layout might both reflect and reinforce changing sociopolitical realities.

From the Field to the Classroom: Developing Pedagogy in Digital Humanities

Chad Keller

For years, humanists have been developing processes for integrating digital tools into the research and documentation of cultural heritage sites and objects. Primarily, these investigations have been conducted by the upper echelon of the university structure, professors and doctoral students. Thus far, there has been little discussion about how the methodologies and applications developed translate to the graduate and undergraduate level, or possibly even within secondary education. Exposing students to
the current digital trends at an earlier time in their academic career will be beneficial to those within academia as well as the general public. The application of digital tools presents new avenues for research and the current excitement surrounding these devices should be harnessed to highlight the significance the field of cultural heritage research plays within society.

Students interested in pursuing professions in an array of history-related disciplines need to be exposed to the current research and application of digital tools much sooner in their academic sequencing. Although a limited number of students will utilize or apply these tools in their profession on a consistent basis, they need to be aware of the benefits as well as how these technologies are being employed within the field. In doing so, students become exposed to the tools and language of the digital historian, which will allow them to confidently and effectively communicate with their peers and professionals currently engaged in the digital humanities.

To that end, courses were developed at the University of Virginia and the Savannah College of Art and Design that expose students to digital technologies and their application in the field. Most students within the humanities have little to no technical expertise and these courses are designed to accommodate students at a beginner level. Technologies discussed include 3D modeling, photogrammetry, photomodeling, real-time visualization, GIS and laser scanning. The courses are not limited to classroom discussion. Students have the opportunity to work directly with the hardware and software being employed in the field. As some of the technology may be cost prohibitive, it is important that students are exposed to free open source software and low cost solutions as well. In addition, students discuss the potential positive and negative impacts integrating these tools have in an academic, professional or public setting.

Developing a new pedagogy around digital tools, which focuses on their integration into the research, documentation and dissemination of cultural heritage sites and objects can potentially create a learning environment that is more actively engaging and empowering for students. As educators, we need to expose students to the benefits these tools have for academic research, as well as how the information garnered can be repurposed for historic site interpretation and other aspects of public history. Only then do we begin to maximize the full potential digital tools have to offer.

Bosutswe Landscapes: Defining Early African Towns through Spatial Archaeometry
Eileen Ernenwein; Carla Klehm; Katie Simon

A research project is underway utilizing a combination of spatial archaeometric methods including low-altitude aerial remote sensing from a UAV platform, on-the-ground subsurface geophysical surveys, and excavations to better understand the Iron Age
landscape in the eastern Kalahari Desert, Botswana. This region is particularly well suited for this project because of the high diversity and density of Iron Age sites and sparse vegetation cover that permits remote sensing. The project includes aerial survey of six hectares with a CineStar Octocopter to photogrammetrically produce infrared and thermal ortho-images and digital elevation models. On-the-ground geophysical surveys including electromagnetic induction (EMI), ground-penetrating radar (GPR) and magnetometry are used to survey three hectares of Mmadipudi Hill, a prominent hilltop site in the region that had received little attention prior to this project but has the potential to greatly improve our understanding of regional dynamics of emerging complexity. These data reveal a village with a central cattle pattern, including a large cattle kraal flanked by enclosed housing clusters. Targeted excavations confirm the presence of houses and associated features and help associate occupational phases with major shifts in the local political economy.

This project seeks to revise outdated notions about how societies in Iron-Age Botswana (550-1650 CE) experienced the change from small, agropastoral groups to centralized power based on increasing involvement in trade across the Indian Ocean. How this change occurred remains a central focus, with increasing pressures on the environment in this marginal semi-arid landscape a likely contributing factor. To investigate this notion we have selected the Bosutswe region, a major trade bottleneck situated on the eastern edge of the Kalahari Desert. Although the polity of Bosutswe has been well studied, the surrounding sites are almost entirely unknown. In previous research, early cities have been considered separately from their surrounding landscape, and urbanism credited as the driving force for the development of complexity in the region. We propose that the small-scale villages, pastoral sites, and likely hunter-gatherer camps that clustered around these early urban centers were not only crucial for the success and maintenance of these polities, but also were integrally involved in how inequality first developed in the region. This project is just beginning to discover a mosaic of sites that interacted on the landscape that provide a very different view of the composition of early complex societies and how the origins of inequality developed in prehistoric sub-Saharan Africa.

**Intra-site applications**

**Using Orthophotography and photogrammetry in Preventive Archaeology, methods and limits. The case of Quincieux Grange Rouge site near Lyon (France)**

*Bertrand Moulin; Oliver Barge*

In the particular framework of French rescue archaeology, our aim is to identify and analyze the archaeological information from sites concerned by development projects. We are helped by mechanical means significant on lands.
Archaeological information (spatial and descriptive), eco- and artefacts collected during this excavation will be the only remains left to document each site after its destruction, and, therefore must be preserved for any future study. In the rescue problematic, cost and time are important brakes to the collection of the spatial and descriptive data on the field, and also during the post-excavation investigation.

In this context, the acquisition of orthophotography at the scale of excavation site is a growing need for "visual" backup of the site and for public relation. Moreover, this document is an essential tool that increases the information available and the post-scraping understanding directly on the field. It promotes change in archaeologist’s perception of the site, and offers to combine the horizontal angle of a classic view, at ground level, and the air dimension, from wide-angle to centimeters details.

In 2013, a campaign to acquire an orthophotography was carried out on the site of Quincieux – Grange Rouge, in France near Lyon. The campaign fit into the use of a Gis and a database for the management of a large excavation site in rural area (around 92000 m²). This approach is based on collecting and archiving information into a database (DBMS) using PC-tablet on the field, in combination with a GIS implemented with the latest archaeological survey for the spatial information.

The results are an orthophotography with X m resolution and a digital surface model with X m resolution. These documents promoted on the one hand, the establishment of a photo-interpretation beneficial to the comprehensive cartography of remains in place. On the other hand, they facilitated the identification of coherent archaeological structures hardly perceptible on the field.

The implementation of these tools revealed some limits concerning the use of automated methods of remote sensing comparing to the complexity of archaeological remains. Finally, the treatment’s possibility with high-resolution topographic DEM exceeded the spatial resolution used in the context of archaeological analysis.

This presentation aims to describe in detail the methods used to create the digital orthophotography and the DEM. Benefits and issues of these documents are detailed, focusing also on the perception and changes in archaeological work.

New Approaches to the Polysensing Environment

Bill Seaman

Seaman has been exploring ideas surrounding Polysensing for over a decade. The notion has been to articulate a multi-modal sensing environment that is linked to a networked virtual space, related database and intelligent media connectivity system. The main concept is to create a stream of “sensed” multi-modal pattern flows as derived from a series of different linked sensing systems including multiple sensors on a chip
that might function in conjunction with other sensing technologies that reside at a given site. The time-based layering of data from differing sensors begins to present coherent *data-objects* in a similar fashion to that of the how the human builds up knowledge of context over time. Once can also link and/or intermingle "associated" "informational" data of relevance – e.g. coherent mark-ups of differing digital objects, key-word meta-tags, etc. The potential is to link an Internet of things with particular spatial environments and distributed researchers from differing, yet related fields. Additionally one seeks to extend these multi-modal sensing environments with new forms of light sensors enabling intelligent transduction of multi-modal sensor data. The potentials of new forms of bio-abstractions robots that might have mobile Polysensing environments linked to particular "learning" systems are also of value. One also seeks to create a flexible “Grammar of Attention” for the sensors that is easily coded via an “Emergent Intention Matrix” – object –based coding system. Although such a system can be applied to many different kinds of environment— scientific, artistic, and humanities related, one can easily see the specific relevance of such a project to CyberArcheology.

**Inter-site applications**

**Integrated Approaches: Combining SFM and scene-level modeling for data exploration, interpretation and publication of the excavations at Gabii (Italy)**

Rachel Opitz; Matt Naglack; Tyler Johnson

Archaeology, and classical archaeology in particular, has long engaged with questions of the formation and lived experience of towns and cities. Such studies might draw on evidence of local topography, the arrangement of the built environment, and the placement of architectural details, monuments and inscriptions (e.g. Johnson and Millett 2012). Fundamental to the continued development of these studies is the growing body of evidence emerging from new excavations. Digital techniques for recording evidence 'on the ground', notably SFM (structure from motion aka close range photogrammetry) for the creation of detailed 3D models, and for scene-level modeling in 3D have advanced rapidly in recent years. These parallel developments have opened the door
for approaches to the study of the creation and experience of urban space driven by a combination of scene-level reconstruction models (e.g. Klein, Vermeulen and Corsi 2012; Paliou 2011; Paliou 2013) explicitly combined with detailed SFM or scanning based 3D models representing stratigraphic evidence. In this context the extended thought exercises conducted through the modeling process, iterating through rounds of hypothesis testing and data exploration, can draw on a combination of documented remains and reconstructions. For the writer and modeler there are real challenges in highlighting the important contributions of non-spatial data in an explicitly visual and spatial environment, and in making visually explicit or tacit the divide between the reconstructed and the archaeological remains, while for the reader and interpreter it is essential to understand the subtle but crucial impact of the design of the user interface on the interpretation these models. In this presentation we focus on the impact of design choices on the part of the authors and modelers, making explicit the chain between the reading/viewing environment and high level interpretations about the use of spatial and visual cues to guide interaction with(in) urban places, a topic which continues to be addressed by archaeologists and classicists working in the digital humanities, e.g. in the context of domestic space at Pompeii by D. Frederick (2013) and in the context of rural and ritual landscapes by G. Earl and D. Wheatley (2002). We take examples from ongoing work within the Gabii Project and the 21st c. Data, 21st c. Publications. 3D Model Publication and Building the Peer Reviewer Community (Kelsey Museum, University of Michigan & CAST, University of Arkansas) as cases in point By using the example of Gabii, an ongoing excavation, we illustrate the particular importance of understanding the links between media and message, beyond paradata and metadata (3DVISA 2007), when making interpretations based on the typically partial evidence available during an ongoing excavation of a town with imperfect preservation, in contrast to the situation at atypically thoroughly exposed and well preserved sites like Pompeii or Herculaneum. In discussing our own evolving practices in engagement with the archaeological record created at Gabii, we hope to highlight some of the challenges and implications for analysis and publication.

**Lidar Applications**

**Modeling Archaeological Landscapes in Peru with Ground based LiDAR**

*Patrick Williams*

Ryan Williams, Ana Cristina Londono, Megan Hart, & Donna Nash

The geomorphology of arid southern Peru has been sculpted by an impressive anthropogenic landscape: kilometers of desert transformed into agricultural terraces abandoned for the past 500 and 1000 years; these include the Inka (1450-1532 CE) agricultural systems at Camata and the Wari (600-1000 CE) agricultural systems at cerros Mejia and Baúl. In this paper, we evaluate the use of ground based lidar for sub-
centimeter resolution surface mapping of terraced Andean agricultural systems, as well as its suitability for fine-scale surface mapping for reconstruction of micro-elevation models of past anthropogenic landscapes and for the understanding of erosion processes in arid lands. A major source of soil loss in dryland areas is the abandonment of agricultural fields. The lack of maintenance of the infrastructure of these once productive agricultural systems accelerates the loss of productive soil, and causes land desertification. Erosion patterns can be used for estimation of erosion rates on disturbed areas under development or intense agricultural use in dryland environments. These rates give a sense of the magnitude of degradation of poorly maintained earthworks in dryland regions. We also examine the original hydrological flow networks of these systems and assess the decision points and social control of water inherent in the hydrological system. By recreating the details of the man-made hydrology, we chart the decision-making structure of water flow in systems pertaining to different time periods and different political regimes. It is our contention that the management decisions inherent in water distribution reflect different strategies and priorities in political structures in Andean prehistory. We can thus assess how political strategies affect water distribution networks and in turn compare that to erosion models to assess systemic vulnerability in agricultural landscapes and how they are affected by changing environmental and climate conditions.

**Terrestrial Lidar and GPR investigations into the Third Line of Battle at Guilford Courthouse National Military Park, Guilford County, North Carolina**

*Stacy Curry*

Stacy Curry, Roy Stine, Jerry Nave, Linda Stine, Junshan Liu, Richard Burt, Charlene LeBleu, Jacob Turner.

In the summer of 2011 a joint geophysical and archaeological field school was held near the third line action at the battle of Guilford Courthouse, March 15, 1781, located at the Guilford Courthouse National Military Park, Greensboro NC. The location of the third line is under debate by historians and archaeologists. A ground penetrating radar (gpr) survey revealed a linear feature approximately 50 cm in depth, varying in width and trending north south for approximately 68 m before entering a heavily wooded area. Excavation of a narrow trench towards the end of the field season revealed a colonial surface, possibly a road or gully, covered in fill dirt. Both a road and a gully have been discussed in the literature, and their discovery would yield important clues to the location of the third line. The surface of this buried feature was slightly concave. In November of 2013 a team from Auburn joined UNCG and NC A&T SU researchers with a terrestrial LiDAR survey to see if a highly detailed elevation map could trace the surface manifestation of the feature into and through the wooded area. This paper will discuss the results of the terrestrial LiDAR survey in conjunction with the gpr investigations.
Robot meets history

Dorit Borrmann

Archaeology is a historical science of high social interest. It studies the human being and its legacy, such as buildings, tools and art. Cultural heritage sites can be found all over the world and they tell us the story of humanity in different areas of the world. Remote sensing has become state of the art in modelling archaeological sites. This way of digitization of entire buildings or areas gives as a unique opportunity to preserve the current state of prehistoric buildings and to join forces of experts all over the world.

Collecting the data is tedious work. It includes finding the best position for a laser scan, moving the equipment to the position and georeferencing of the scanning position. Letting a robotic system take over this work reduces the time spent in the field by 75 % and decreases the impact to the sites. We present the robot Irma3D, that was designed create in a tele-operated fashion digital 3D models of environments. This paper describes the setup and the capabilities of the robot and presents results of experiments carried out at cultural heritage sites.

The robot was tested in two scenarios, Ostia Antica and the Würzburg Residence. Ostia Antica is a large archeological site, close to the modern suburb of Ostia (Rome). Due to the exceptionally well-preserved state of the city, Ostia is of immense interest for the study of the Roman Empire. The Würzburg Resdience is a baroque palace in the city
center of Würzburg, Germany. Being built in the 18th century and heavily damaged during World War II it was laboriously reconstructed and named a UNESCO World Heritage Site in 1981. The large unsupported trough vault designed by architect Balthasar Neumann, large colorful paintings by painter Giovanni Battista Tiepolo and fine stucco work by stuccoist Materno Bossi in many of the almost 400 rooms are unique examples of baroque style.

In this paper we describe the data collection with the robot Irma3D in these two renowned historic sites, the post-processing needed to create a full 3D color model and present the resulting models from a garden house in Ostia Antica (http://youtu.be/sf-gq5xLalC), the White Hall (http://youtu.be/_wPug_So_iE) and the Imperial Hall (http://youtu.be/jKVxLvu7Pk) at the Würzburg Residence. The results can interactively be viewed in a 3D viewer or with an Oculus Rift.

Application of LiDAR ground-surface surveying technology to surface survey of topographically complex urban settlements: Tell es-Safi/Gath, Israel

Haskel Greenfield; Deland Wing; Aren Maeir; Itzhaq Shai

This paper will introduce and discuss the utility of a LiDAR ground-based approach to data collection and analysis within archaeological sites that are complex topographically and stratigraphically. LiDAR technology can capture millions of data points in a brief span of time allowing for more subtle imagery and multivariate analysis far beyond simple photogrammetric data capture approaches. In recent years, LiDAR technology has been utilised within archaeology in two ways. The more common approach is its use for aerial survey in order to capture three-dimensional imagery of topography and other landscape features. The second, which is far less common, is ground survey to capture a more detailed 3D image of architectural units upon the conclusion of an excavation or excavation season. It allows for disparate parts of large sites to be integrated into a single analytical unit. While LiDAR survey is often proposed as a solution to the problems of archaeological digital data capture, there are many pitfalls that must be considered. In this paper, we will discuss various methodological issues and present the first run of data analysis whereby all of the areas of a large multi-period and topographically complex early urban settlement are integrated into a single analytical unit. Data from the archaeological site of Tell es-Safi/Gath, Israel will be used to demonstrate the utility of this kind of approach to data collection and analysis.
Integrating terrestrial and airborne LIDAR with structure from motion photogrammetry for documenting industrial heritage landscapes in the Central Appalachians

Charles Yuill; Peter Butler

This paper will discuss current and emerging efforts documenting industrial and other cultural features and landscapes in the Central Appalachians primarily from the late 19th and early 20th centuries. The focus is primarily on historic coal mining communities though other features such as depression era communities, lumbering towns and early railroads, and iron furnaces will also be examined. The technologic emphasis of our efforts has been on integrating a couple of related but up until now disparate technologies to permit multi-scale documentation of historic/heritage features and areas. We are utilizing airborne lidar (Optech 3100) for applications such as developing landscape context and searching/prospecting for landscape anomalies that might be related to past disturbances from past mining, timbering, and town establishment and development. We are integrating airborne lidar with terrestrial lidar for highly precise documentation of specific features and structures. Utilizing extended occupancy gps methods we obtain less than two-centimeter agreement between the airborne and terrestrial data sets. We have also integrated imagery data with lidar data sets using emerging structure from motion (SFM) photogrammetric methods. These methods and the results are being used to document remaining features, developing supporting narrative and analytic summaries of the areas and structures, and developing education and instructional materials for a range of potential audiences. Though we will examine a number of case study project areas, the focus will be in the town of Gary, West Virginia which is located in McDowell County, which is one of the poorest counties in the United States, but is also within the federally designated Appalachian Coal Heritage Area and as such has cultural resource documentation and protection as a priority – within an intensive industrial landscape. Gary at one time housed the largest coal mine in the world with a population in the thousands, but now has only a few hundred remaining residents. In addition, modern large-scale surface mining methods have been significantly altering large numbers of potentially historically significant architectural and landscape features that are artifacts of early historically significant 20th century underground mining. Gary was essentially where the metallurgical coal mining industry was established in the United States, as the major source of coal for the U.S. Steel Corporation. Our focus continues to be on identifying, prioritizing and documenting significant structures and landscapes as they are altered by current large-scale surface mining methods.
A methodology for using ALS data for reconstruction of historic road networks

Willem Vletter

Historical roads and paths tend to be better preserved in heavily vegetated or forested areas. Airborne Laser Scanning (ALS) is the only remote sensing technique able to visualise on a large scale the micro topography of these landscapes. Indeed, in the archaeological field a lot of new features have been detected or reconfirmed thanks to ALS. However, it is time consuming and costly to map manually the enormous amount of features, especially roads and paths.

Another issue is that once roads and maps have been mapped or detected, it remains difficult to determine the age of the roads and paths. This is a problem that is not easy to solve, especially with regard to older roads and paths. A third issue is that detected road and path networks reflect only partly the whole range of road and path networks which once existed. A final issue is that the geometry (like shape), location and attributes (like ownership) of roads and paths can change over time.

In order to address these issues we developed a methodology existing out of four steps. In the first step the (semi-) automatic visualisation and extraction of linear features from ALS data is tackled. In the second step a method is presented to determine the relative chronology of historical roads and paths. The third step deals with the predictive modelling of unknown networks. The last step combines a 3-D environment with a time element, resulting in a temporal-spatial visualisation of the road and path networks found. This visualisation serves not only presenting purposes, but is also used as an analysis tool.

The developed methodology not only leads to the reconstruction of historical road and path networks, but also contributes to the scientific research on the use of ALS data. Moreover, the outcome of a reconstruction of historical road and path networks can be used as an input for cultural heritage management on a large scale.

The Use of LiDAR to Detect New Settlements in the Mosquitia, Honduras

Christopher Fisher

The Mosquitia region of Honduras, long known to be an important archaeological region, has seen relatively little archaeological research. Here we present results from a project that has used LiDAR to document the cultural and ecological heritage of three previously undocumented areas within the region. These results include two large urban centers and numerous smaller settlements embedded within a human engineered landscape including terraces, canals, and roads. This record comprises a significant
database that provides critical baseline data for modern conservation and preservation efforts.

New Perspectives on Purepecha Urbanism Through the Use of LiDAR

Christopher Fisher

The evolution of the ancient urban form can yield insights that are relevant to modern stakeholders and policy makers. Traditionally this work has involved decades of full-coverage archaeological survey and excavation before such insights can be reached. High-resolution aerial-based LiDAR has the potential to transform our understanding of ancient cities by providing comparable data in a fraction of the time. Limiting factors, however, are a lack of techniques and protocols for the analysis, visualization, and interpretation of these data. Here I present techniques and lessons learned from the exploration of a LiDAR dataset for the ancient city of Angamuco, Michoacán, Mexico. This work has dramatically changed our understanding of the urban form and social complexity in Western Mexico.

LiDAR at Angamuco, moving beyond visual interpretation in the use of LiDAR

Stephen Leisz

Since the early 2000s LiDAR has been used in various field settings in support of archaeology. In 2010, after two fieldwork seasons devoted to the mapping of structures of a previously unknown settlement on a malpais in the Lake Patzcuaro Basin of Mexico, 9 km² of LiDAR data were obtained for the site. During the next two field seasons LiDAR derived products were integrated into the fieldwork and mapping efforts. This paper describes the use of LiDAR within the Legacies of Resilience project in the Lake Patzcuaro Basin, Michoacán, Mexico. It details the creation of the LiDAR derived products used in the mapping effort, the results of the LiDAR supported ground survey and mapping and a comparison to the previous full-coverage surveys which used sub-meter GPS surveying methodologies to map structures within the newly identified pre-contact urban area. It also explains current efforts and results of automating the extraction of archaeological features from LiDAR point clouds and LiDAR created digital elevation models. It is our belief that the automatic extraction of features from LiDAR products will increase the usefulness of LiDAR in the archaeological context.
Ground Penetrating Radar is nowadays increasingly applied as a high-resolution large-scale archaeological prospection method. The efficient cost-effective data acquisition with few centimeters spacing interval over large areas allows for a rapid mapping of archaeological sites. However, in order to achieve a comprehensive documentation of the investigated structures in terms of specific typology, relative chronology and state of preservation, a relatively time consuming interpretation process is generally required. This is usually performed in GIS environment by digitalizing the archaeological features based on the visual inspection of raster images (2D depth slices extracted from the GPR 3D data volume). Although semi-automatic feature extraction techniques are being developed to improve the interpretation process, in many cases the "manual digitalization" in GIS still remains the most accurate method for the detailed archaeological documentation.

The GIS-based interpretation of GPR data, especially in the case of complex archaeological sites, can require the analysis and management of a great amount of raster images, as well as the editing of many vector features (typically polygons) that have to be appropriately described in the attributes. Moreover, taking into account the three dimensionality of the GPR investigation, 3D modeling of the subsurface features represents a crucial step of the process.
The proposed paper presents a good practice allowing for the efficient GIS-based archaeological interpretation of GPR data, especially with regard to the large-scale applications.

The interactive animation of GPR raster images in an ArcGIS environment and the true 3D modeling by means of “multipatch features” represent key aspects of the work. Particular attention will be given to the strategy applied in generating and managing the 3D objects within the geodatabase, which represents an important aspect of the documentation process. In order to achieve a more comprehensive data interpretation, GPR data are also visualized in form of isosurfaces that are extracted in Voxler and imported into 3D GIS through an optimized workflow, including data conversion and 3D mesh simplification.

“Semi-realistic” 3D interpretation models and preliminary virtual reconstruction of the structures are performed by combining the use of ArcGIS with 3D modeling software (SketchUp). The final result, also suitable for dissemination purposes, is displayed in the 3D GIS environment allowing for the interactive investigation of the 3D models by means of HTML popups. For multi-phase sites, the dynamic evolution of the “archaeological events” can be displayed interactively by means of a “time slider” tool. By considering that the archaeological interpretation of prospection data is a dynamic process, which should require a collaborative and integrative approach, the GIS application has been conceived to achieve transparency and standardization in the archaeological documentation and simplify the data reuse for updates and alternative interpretations.

Different archaeological contexts are analyzed in this work, including the well-known Roman city of Carnuntum and a less known archaeological site in Austria, which preserves the remains of a villa rustica. The work has been conducted in the frame of the IC-ArchPro project at University of Vienna in collaboration with the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology.

Alcatraz in 3D: Terrestrial laser scanning and subsurface ground-penetrating radar reconstruction of the prison and Civil War era historic fortifications at “The Rock”

Timothy de Smet

Over 2012 and 2013 we conducted a cultural resources assessment and historic preservation project with Jason Hagin, Leo Barker, and Peter Gavette of the National Park Service on Alcatraz Island with terrestrial laser scanning and ground-penetrating radar. The island was placed on the National Register of Historic Places as a historic district in 1976, shortly after its 1972 transfer to the National Park Service as one piece of the Golden Gate National Recreation Area in San Francisco, California. Alcatraz is
most (in)famous for its brief period as a Federal Penitentiary (1934-1963) due mainly to the exploits, riots, and escape attempts of its prisoners. For the vast majority of Alcatraz history, however, it was a military fortification – Fortress Alcatraz - under the U.S. Army. As the need for harbor defense diminished, the island was converted into a military prison during the 1860’s. In 1933, the military prison was transferred to federal control leading to the establishment of the high-security penitentiary. The conversion of the island to a prison greatly reduced the surface record of this historic period. An analysis of georectified historic maps showed that historic masonry and earthen work fortification structures once stood in the Parade Ground and Recreation Area of the island. Ground-penetrating radar was used to detect the presence, integrity, and extent of these significant historic remains below the islands current prison façade. The Recreation Yard at the Alcatraz high-security federal penitentiary served as a secure outdoor facility where the prisoners could take exercise. The facility, enclosed by a high perimeter wall and sentry walk, included basketball courts, a baseball diamond, and bleacher-style seating. The Recreation Yard was constructed in 1908-1913 directly over existing earthen fortifications, namely a trio of embankments known as “traverses I, J, and K.” These mounds of earth, connected by tunnels, were in turn built over concrete and brick magazines. In the Parade Ground the South Caponier was largely destroyed by the leveling activities during the 1870s. The processed GPR sections show good correlations between radar reflection events and the locations of the buried fortification structures derived from historical map analysis. A 3-D data cube was constructed for the Recreation Yard and show that traverse K, in particular, has a strong radar signature. The harsh climate of the bay continuously deteriorates the concrete structures of the later prison. Laser scanning was undertaken to obtain a current 3D reproduction of the islands prison façade. The integration of GPR and laser scanning data was used to create a ‘total’ 3D reconstruction, which allowed for a greater understanding of the process of change over time on the island in a 3D context.

An integrated archaeological prospection and excavation approach at the Neolithic circular ditch system in Hornsburg, Austria

Jakob Kainz

The aim of this paper is to present an approach combining archaeological excavation with geophysical prospection. This is achieved by a combination of magnetometry, magnetic susceptibility, GPR and pXRF measurements, on archaeological features before and during excavation. Soil properties, such as soil colour, organic content, pH, magnetic susceptibility, chemistry and composition are influenced by human activities and these changes can be identified by various prospection methods.

Archaeological prospection in the majority of cases is carried out prior to excavation, in order to map the archaeology for the excavation or for planning procedures. The full archaeological potential of the various prospection methods therefore is not attained; as such measurements can help corroborate excavation results as well as providing further
archaeological data which cannot be seen by the excavator’s eye. Furthermore excavations provide an opportunity to investigate the anomalies allowing for an examination of the processes, whether human or natural, influencing the prospectability or non-prospectability of these features.

This approach provides complementary information for the excavation as well as allowing the examination of the physical properties of archaeological anomalies. This creates a suitable backdrop for a reflexive interpretive cycle between these fields. A better understanding of the physical properties of anomalies is gained, providing an insight into their prospectability but also the anthropogenic or natural processes which created them. Such a framework can then be further applied for an examination of the spatiotemporal relationships of archaeological and non-archaeological prospection anomalies within the surrounding landscape. This can provide a link between past human actions and specific anomaly signatures, adding further archaeological interpretation to the prospection data as well as providing a greater archaeological insight during and after excavation.

Co-authors: Guglielmo Strapazzon, Roderick Salisbury, Matthias Kucera, Wolfgang Neubauer

Using Ground-Penetrating Radar to Study Sites in the American Southwest: New Approaches to An Old Method

Jennie Sturm

In American archaeology, ground-penetrating radar (GPR) has enjoyed its longest use in the Southwest. While this method has long been used to locate features of archaeological interest, much of the focus has now shifted from using this technique as a prospection tool to one that can be used directly in the study of archaeological sites. This reflects an increasing sophistication in the ways practitioners process, interpret, and visualize GPR data, which capitalizes on this method's high-resolution, three-dimensional mapping capabilities. Furthermore, combining these data with other geospatial techniques such as aerial photography and GPS survey means it is possible to associate buried features to surface phenomena, thereby opening up the types of questions that can be addressed while also preserving sensitive archaeological sites. This presentation draws upon examples from the American Southwest, including Chaco Canyon, to show how this approach is being used to reconstruct a site's layout and reorganization of space, study architectural construction, and understand buried features in relation to the larger archaeological landscape. Far from being a simple prospection tool, the use of GPR in archaeology is enjoying a revitalization as advancements in the way geospatial methods are combined generate data that can be used directly in the interpretation of the archaeological record.
Applications of acoustic, magnetometric and topographic submarines devices for an underwater archaeological method research in preventive archaeology

Philippe Pelgas

Pelgas Ph., Wirtz B., Duo Ramila M.

Using of geophysical techniques is an essential component of all investigations for archaeological evaluation on extensive submarine areas in order to have a large wider of the seabed. They can allow us to record abnormalities but in many cases after an interpretation’s step, it is an absolute necessity to dive for further verification. But between ten and several hundred or thousand hectares, it is really important not to spend time looking for abnormalities. And it’s important to choice an adapted and evolutionary methodology.

Four studies will be discussed on extensive submarine areas.

The first study used a multibeam sonar Reason 8101 (Castro-Urdiales, Cantabria, Spain). This port was important during Antiquity and Middle ages. The survey on 1.78 km² was ordered. A Digital Terrain Model (DTM) was carried out until with a 0.25 x 0.25 stitch according to the depth. DTM can be viewed in 3D, all the points in X, Y, Z were georeferenced. The resolution is so refined that we can see canon balls and spillage of the ship’s cargo, and rock gullies, and with probable traces of shipwreck. Dr Bruno Wirtz was in charge of the rough data to reveal small and size-limited micro-relief, using different kind of original signal treatment with Magsalia process.
The second study was in Reunion Island (France, Indian Ocean) in November 2012. The project of a coastal motorway bridge built on the sea. An Inrap diagnostic was carried out with a geophysical step with a side scan sonar Klein 3900 and a magnetometry with a G882. More than 4710 abnormalities were found. The first calculations were carried out by Geosoft software. The calculation and associated interpretation reduced this number to less than seventy-seven targets that were explored.

The third study was a survey in 2012 covering 2 km² for the development of Calais’s harbour (France) with magnetometer and side scan sonar. The geometry of the explored area and the well documented set data record makes a DTM of the sea bed in the area of survey possible, with one meter range of interpolation. Hence a variant of the Magsalia process focuses on the depth of burying the abnormalities.

The fourth study was in Porto-Veccchio’harbour (Corse Island, France) in 2013 for preventive intervention. First step was to do the georeferencement of the area with a multibeam and after with a subbottom profiler. An interpretation of the subbottom by the Service Hydrographique et océanographique de la Marine (SHOM) reveals abnormalities. (Shipwrecks, paleo-dune?).

In conclusion the underwater preventive archaeological development and the use of geophysical tools use will allow the artefact's discovery to be fine tuned as well as to

Ground-Penetrating Radar, Magnetometry, and Excavations at the Mississippian Pile Mound Site, Upper Cumberland Plateau, Tennessee, USA

Jeremy Menzer; Eileen Ernenwein; Jay Franklin

Ground-penetrating radar (GPR) surveys using 400 MHz and 270 MHz antennas and a GSSI control unit, paired with magnetometry surveys and targeted excavations at Pile Mound reveal a large rectangular structure situated on top of the mound and a broad distribution of associated features over the ca. 1.5 ha site. Geophysical survey, including the addition of electromagnetic induction (EMI), will continue in the coming years. Magnetometry conducted with a Bartington Grad601-2 fluxgate gradiometer was used to survey the entire site, while the GPR survey’s purpose was to investigate the three-dimensional details of the rectilinear structure within the mound and layering related to mound construction. GPR data were collected in closely spaced transects in two orthogonal directions to produce a detailed three-dimensional data set for interpretation and visualization. Targeted excavations were used to test hypotheses based on the geophysical data including the nature of pit features, mound architecture, and construction.
Pile Mound provides a unique opportunity to better understand the Mississippian (AD 900-1600) occupation in the Upper Cumberland Plateau of Tennessee. The mound itself has been protected by the landowners for generations and has never been plowed, while most other mounds in this region have been all but erased by modern agricultural practices and reservoir inundation. Indeed, our understanding of the Mississippian culture in this region is almost completely lacking, and relies directly on excavations of the Croley-Evans (15Kx24) mound in Kentucky, some 80 km away. In the most prominent Mississippian areas, located on the large floodplains of the Mississippi, Ohio, and Tennessee River valleys, the culture area can be characterized by the cultivation of maize and local fauna. These towns commonly contain 1-3 platform mounds topped by a rectangular structure and were governed by large chiefdoms broken into an elite and common class. Many less documented sites occur along the northern periphery of these chiefdoms in upland areas, which have been characterized by a larger dependence on local resources and only one platform mound within a complex. These upland sites are typically broken into smaller polities rather than a singular large chiefdom. This project effectively doubles our knowledge of Mississippian mound sites in the Upper Cumberland Plateau.

Large-Area Magnetic Gradient Survey at Native American Earthwork Sites in Ohio, USA

*Jarrod Burks*

Ohio is one of the first regions in the United States where remote sensing was used to make observations of archaeological sites. The large geometric earthen enclosures of the Adena and Hopewell peoples (c. 300 B.C.-A.D. 400) have long attracted scholarly interest, ever since the first maps made of the earthworks in the late 18th century. During the 19th century, archaeologists and other enthusiasts debated the accuracy of early maps and endeavored to produce ever more accurate, measurement-based line drawings of the larger and more famous sites, leaving most of Ohio’s approximately 600 sites unmapped. By the end of the 19th century, agricultural plowing and urban development had seemingly destroyed most of Ohio’s ancient earthworks, flattening the embankment walls and filling in the ditches, and most researchers had turned to excavating mounds. However, early aerial photography in the late 1920s and early 1930s, especially by Dache Reeves, showed that many sites were still visible from the air and that one could even discover previously unknown earthworks. Reeves’ findings should have sparked a revolution in earthwork mapping, but to this day few archaeologists have put available photographic resources to serious, systematic use in the study of earthworks. Though somewhat slow in taking hold, geophysical survey is once again revolutionizing our understanding of Ohio earthworks. To date, geophysical surveys at about three dozen earthwork sites have found that these sites are often much different than their 19th century maps, and they have led to the discovery of two previously undocumented sites. Magnetic survey, in particular, has revealed major differences not only in size and shape but also in the presence of previously
undocumented enclosures, large post circles (i.e., wood henges), and strategically placed pit features and posts. Because of the immense size of many sites, complete-coverage surveys are rare. In this presentation I quickly review a range of geophysical discoveries at a selection of sites from the last ten years. This prelude sets the stage for the presentation of new, large-area (10-30 hectare) magnetic gradient survey results from sites in Hopewell Culture National Historical Park. These surveys resulted in the detection of innumerable pit features, two post circles, a new enclosure, feature complexes at the centers of some of the large enclosures, and many other subtle differences in the way these earthworks were laid out as compared to the 19th century site maps. Throughout, LiDAR-based digital elevation models and aerial photographs (old and new) are used to supplement the geophysical data.

Archaeological Compounds at the Southern Brazilian Coast

Tiago Attorre; Paulo DeBlasis; Stephanie M. Sullivan

Shell mounds and middens are well-known worldwide occurrences that inspired the development of early scientific archaeology. In Brazil, there are more than a thousand shell mounds registered as archaeological sites and since the nineteenth century they have been a subject of investigation. Massive shell mounds, known as sambaquis, are found along the southern Brazilian shore in a very dynamic Quaternary environment. Past investigations have always focused on the mounds themselves. We will present the preliminary results of a project aiming at off-mound contexts, examining the surroundings of the great shell mounds at the southern coast of Santa Catarina in search for elements that will add to the modeling of the social complexification of coastal societies between 7,500 to 2,000 years BP. Extensive remote sensing with Ground Penetrating Radar (GPR), alongside a GNSS RTK system and a magnetic gradiometer, have been used to map buried structures within dune fields, as well as collect radar profiles to survey large extensions in an attempt to reconstruct the depositional scenario during that period. At the Figueirinha area, we detected six buried archaeological structures, four of them apparently related to the moundbuilders culture. One of these structures is an unsuspected “U” shaped mound whose dimensions, 69 by 51 meters wide and 2 meters tall, surpassed expectations.
The Late Bronze Age (c. 1700-1100 BCE) on Cyprus witnessed the profound transformation of the island’s sociopolitical organization as well as the emergence of its first cities. The Kalavasos and Maroni Built Environments (KAMBE) Project is an investigation of the relationship between these urban landscapes, the new patterns of social interaction and experience they generated, and the social changes that resulted. A central focus of the project has been the integration of a number of terrestrial and aerial remote sensing methods for the detection, recording and analysis of the archaeological remains of Cyprus’s earliest cities.

In this paper I present and assess the KAMBE Project’s ongoing efforts to understand urban place making at Kalavasos-Ayios Dhimitiros and Maroni-Vournes/Tsaroukkas, located in neighbouring river valleys in south-central Cyprus. While both sites were partially excavated in the 1980s-90s, less than five percent of either site has been recovered, making it impossible to understand how these cities shaped the movement, interactions, and experiences of residents and visitors alike. Our work includes ongoing archaeogeophysical survey using magnetometry and ground-penetrating radar (GPR) in...
an effort to detect the buildings and infrastructure of these urban centers. High resolution GPR survey at Kalavasos has revealed a previously unknown monumental building and other urban features with incredible clarity, allowing the precise mapping of rooms and doorways. This is augmented by the use of aerial methods, including an unmanned aerial vehicle (UAV) equipped with a thermal camera capable of detecting minute differences in ground surface temperatures that might be indicative of subsurface archaeological features. Using a digital camera, the UAV has also provided images for a photogrammetrically-derived digital elevation model. At the same time, the project has been undertaking the recording of the extant architecture of both sites, as well as newly excavated remains at Kalavasos-Ayios Dhimitrios, using 3D laser scanning and close-range photogrammetry. These methods serve as a basis for the 3D modeling of urban spaces at both sites in an effort to better understand the interplay of movement and visibility in the creation of urban landscapes. I conclude by assessing the potential and limitations of these various remote sensing methods to shed light on the place-making activities of Cyprus’s Late Bronze Age inhabitants – a dynamic process through which social and material relations were completely transformed.

Container and contents: analogies and senses of the past in the museum

Alicia Jiménez

The material reflection of ideas that link the classical past with power and the origins of Western civilization can be seen a myriad of replicas: senate buildings, banks, and libraries resembling Graeco-Roman temples. Museums are particularly interesting examples of reinterpretations of ancient architecture and spaces intended to give us a sense of the past as people of the past experienced it. The "container" mimics ideal architectonic structures that would have once housed Greek or Roman artifacts in their original context, interestingly, without being faithful to the original.
In this paper I will analyze, among other examples, the Getty Villa in Malibu, a recreation of the Villa of Papyri, located in the outskirts of Herculaneum and destroyed by the eruption of the Vesuvius in 69 AD. The "authenticity" of the reconstruction emanates from the precise ground plan made by the engineers in charge of the excavations conducted by the King of Naples in the 18th century, even if most of the villa remains even today underground. However, the main purpose of P. Getty was not creating an accurate copy, since the building in Malibu is in fact a pastiche that includes fragmentary reproductions of the remains of various ancient dwellings from various sites around the Vesuvius (such as Herculaneum, Pompeii and Oplontis). The final aim is not similitude but verisimilitude. It was meant to recreate, in the form of a (fake) archaeological site with intact-"ruins" (I quote the Getty Museum’s webpage) "how the ancient Romans might have envisioned their surroundings". Paul Getty, who had been touring Europe while at college at Oxford and owned a villa in the Bay of Naples himself, wanted not only to get a new space to display the objects that were piling up in their ranch-museum, but also arouse "feelings" in the observer. He wanted the visitor to become Roman; to feel what the Romans back two thousand years ago felt walking around the garden, the rooms and the peristyle of the Roman villa. According to the Getty webpage "Paul Getty's original vision for the villa remains an enduring one: a setting that brings the spirit of the ancient Greek and Roman civilization and the art of the ancient Mediterranean to life".

The transformation of "us" in "us into the past" is performed through mimetic representations and "images" of the past and the exercise of the mimetic faculty, the recognition of the past in the present through the recognition of similarity (Taussig 1993: 40). In this sense, the continent in the museum is a pastiche as much as the content: a compendium of objects from different times and places collected to tell a story about ancestry. An authentic recreation of the past is created through a mixture of true originals in display cases and "fake" doubles (models, maps, dioramas, photographs, 3D-recreations) that fulfill a desire to ubiquity.

Cultural Resource Management

Ethics for Archaeologists Using Remotely Sensed Imagery in War-Torn Landscapes: A Case Study in Southern Afghanistan

Anna Wieser

The Water, Archaeology, Landscapes, and Culture (WALC) research group at University of Kansas negotiated the ethical implications of studying southern Afghanistan, a region embroiled in war, using limited access to high-resolution imagery provided in part by the Army Geospatial Center (AGC). Ongoing research includes the study of karez water systems, modern land use and population distribution, and Bronze
Age land use in Kandahar and Helmand provinces. This paper discusses a history of anthropological ethics for studying warzones and working with, or with data provided by, the US military. Twenty-first century archaeologists face increasing amounts of warfare, particularly in Middle Eastern countries such as Syria, Iraq, and Afghanistan. New and continuing conflict forces projects to go on hiatus, often without potential to resume work in the near future. Remote sensing is a common, accessible resource for such scholars to maintain research in areas that are otherwise inaccessible due to war. As a case study, I briefly discuss my dissertation research, which uses a combination of military and civilian remote sensing resources to study Bronze Age southern Afghanistan. WALC studies both modern and ancient populations, and the team’s experience provides insight for other archaeologists navigating ethical issues and interested in pursuing work in other countries at war and/or occupied by foreign militaries.

The case study of Bronze Age land use relies on predictive modeling and remotely sensed imagery to provide an access point to regions inaccessible due to political turmoil. My dissertation queries the relationship between Bronze Age sites and human use of natural resources, particularly water, in Kandahar Province, Afghanistan. The GIS model produced to answer this question incorporates excavation data, environmental proxy data, digital elevation models, and GIS land surface analysis for three archaeological sites in southern Afghanistan. Modern agriculture and occupation relies on the technologically complex and labor-intensive karez system of irrigation, but the labor-intensive nature of this system proves impractical in the current political and military situation. Understanding water use during the Bronze Age is useful for understanding modern water use in the region. This project relies on limited access high-resolution imagery provided to the WALC research group, but additional imagery was purchased and downloaded to complement the data. Multiple concerns were considered during research design and implementation, including those of WALC and Afghan cultural heritage interest groups. This paper reviews these concerns and discusses the potential for future projects using remotely sensed imagery to continue research in war torn regions.
Most of the archaeological excavations conducted in the United States are driven by compliance with the National Historic Preservation Act (NHPA) of 1966. Section 106 and Section 110 of the NHPA both require Federal agencies to consider the effects of undertakings on archaeological sites, inventory (survey) sites on lands under their control, and nominate sites to the National Register of Historic Places (NRHP). Not all archaeological resources can be efficiently investigated with traditional excavations due to their prohibitive size, limited physical access to the subsurface, or the presence of sensitive human burials. These sites can provide an ideal medium for using geophysical methods for mapping intra-site architecture and making interpretations about cultural activities and feature integrity. As geophysics grows in popularity in the United States, it has begun to be used more commonly to address regulatory concerns brought up by Section 106 and Section 110 for cultural resource management. This paper addresses using geophysical methods, results, and interpretations for management purposes at large sites using three examples: two prehistoric Mississippian sites containing mound/village complexes and a historic industrial transportation complex in downtown Atlanta. All three of these surveys were conducted at a landscape scale using ground-penetrating radar and magnetic gradiometer. Additionally, these surveys were all undertaken to identify and/or refine site boundaries, derive archaeological interpretations, and generate primary data for long-term management decisions. In all cases, the end results were only feasible through geophysical investigations.
Multi-granular method for retrieving digital Tangkha images

Chuansheng Liu; Xiang Fei

Based on quotient space and granular computing theory, the image retrieval process is analyzed, and a multi-granular method based on quotient space is proposed for digital Tangkha image retrieval. With the proposed method, an image is divided into different granularities based on hierarchical thinking, and different quotient spaces are constituted according to different behaviors under different granularities of the image. The synthetic features are obtained by composing the attribute functions at different granularity levels based on the theory of composing multi-granularity attribute functions in the quotient space. Finally, the images are retrieved by the synthetic. The experiment showed that the method effectively retrieved digital Tangkha images.

Magnetometry and its use in the Bakken Oilfield

Timothy Dodson; Jessica Bush

The use of magnetometry for detecting archaeological features is nothing new. It has been proven effective in detecting both prehistoric and historic features in a wide variety of natural environments. While this technology has been implemented in North Dakota in the past, its use has largely been focused on Plains village research projects; examples include the Knife River Indian Villages National Historic Site and Double Ditch Village State Historic Site.

Rapid expansion of the Bakken oilfield in northwest North Dakota has required the archaeological survey of a large amount of private, public and Tribal lands. The increased amount of cultural and Tribal properties identified has led to a growing
concern about how to protect these resources within the cultural landscape. Federal and tribal response has led to changes in Section 106 implementation.

In an effort to protect cultural resources, while keeping pace with the ever-increasing demand for oil and gas expansion, new technologies and methodologies are being introduced. Recent discussions with the State of North Dakota, federal agencies, private companies, and local Tribes has led to the implementation of magnetometry on oil and gas projects. Specifically, the magnetometer has been used around prehistoric stone feature sites identified by either archaeologists or Tribal members.

Typical stone features found in North Dakota include navigation and burial cairns, effigies, arcs, and stone circles. Due to heavy vegetation, stone feature sites typically have poor ground surface visibility and the site boundaries can be hard to define. Based on past archaeological excavations and ethnographical accounts, these sites also have the potential to contain intact subsurface features such as hearths, occupational layers, and burials. In most cases, the Tribes are reluctant to approve subsurface testing due to spiritual and cultural reasons. To ensure site protection and avoidance, well-defined site boundaries need to be established. The ability to better define these site boundaries will allow archaeologists to better understand stone feature sites while respecting Tribal cultural traditions.

Traditionally, these sites have been avoided by establishing an arbitrary site boundary and construction avoidance buffer. Arbitrary site boundaries average 50 to 100 feet in diameter and avoidance buffers can extend as much as 300 feet beyond the site boundary. No construction can take place within the site boundaries or avoidance buffers, which has led to complications during project planning and the abandonment of several projects.

Magnetometry is a way to reach a compromise between oil and gas development and the protection of archaeological and Tribal resources. This paper will detail the steps that were taken to implement the use of magnetometry in the Bakken and the results of several undertakings.

**Drones and UAV**

Methods and techniques of UAV based cliff-painting investigation in complex terrains using the Zuo Jiang cliff painting as an example

Li Zhe; Shao Hao-ran; Yan Yu

Cliff paintings turn out to be difficult for archeological investigation among the rock painting heritages, those in Zuo Jiang of Guangxi province are located in most complex terrains. It is difficult for surveyors to climb up to the front of the cliff or the nearby caves to carry out the survey. The use of UAV close-range shooting has some potential risks and limitations. This thesis gives a brief account of the UAV-based survey of the Zuo Jiang cliff paintings, danger disposal, multi-level image acquisition, the finding of new
cliff paintings and other preliminary achievements. It explains the strengths and weaknesses of UAV-based shooting of cliff paintings, caves and similar relics. The case study helps to analyze the cliff environment, its influence on UVA performance such as turbulence and the range of loss GPS signal, as well as the basic operational methods and techniques used in close-range shooting, mapping and archeological investigation of cliff paintings in such environment, including takeoff/landing tactics, flight mode, safety strategies, equipments selection and adjustment etc. Our experience on this front enables us to carry out future low-altitude survey on cliff paintings in a safer and better way. The thesis also discusses the necessity and main applications of Micro UAV-based laser scanning and multispectral remote sensing technologies in the archeological investigation of cliff paintings and caves. Photogrammetry, micro-Lidar and multispectral shooting are three important parts of technology based on UAV platform for cliff-painting investigation.

3D Recording in the documentation of archeological excavations
Stefano Campana; Matteo Sordini; Francesco Brogi

The scientific community is now relatively of one mind in acknowledging the added value brought by the application of modern technologies of three-dimensional survey during the documentation, interpretation, analysis, management and dissemination of the spatial data that plays a primary role in all aspects of archaeological research. In the field of archaeological excavation it is undeniable that the essentially destructive and unrepeatable nature of the method makes it imperative to employ recording systems that are as sophisticated, accurate and up-to-date as possible at the time the work is undertaken. In the context of the present day the most relevant techniques in this respect are undoubtedly photogrammetry and laser scanning. In the last decade the LAP&T research team at the University of Siena has developed a workflow based on close-range photogrammetry and laser scanning, both at ground level and using UAV and related systems at low altitude, aimed at providing fast, detailed and standardized documentation of excavation evidence. The aim of this paper is to show through selected case histories the results achieved by the team in this field of application and to discuss further possible developments.

UAV-based aerial thermography and archaeological geophysics at the Collins Mound site, Arkansas
Stephanie Sullivan; Jessee Casana; Adam Wiewel; Autumn Cool; Tiago Attorre

This paper presents results of recent UAV-based aerial thermal imaging and other geophysical prospection methods at a possible Early to Middle Mississippian period (ca. AD 900-1400) civic ceremonial center known as the Collins Mound site in northwest
Arkansas. Geophysical surveys employing magnetic gradiometry and ground-penetrating radar have produced excellent results, revealing a large number of rectilinear mortuary structures buried beneath the constructed mounds at the site. We also experiment with rarely utilized aerial thermal imaging, collected using a handheld thermal camera mounted on a GPS-guided octocopter and processed in photogrammetric software. Night-acquired thermal imagery is processed against daytime-acquired near-infrared imagery to help distinguish cultural features from thermal signatures caused by vegetation, topography and other factors. A comparison of thermal imagery with other geophysical datasets demonstrates the largely unexplored potential of thermography to reveal subsurface archaeological features over large areas, if at a coarser resolution than traditional geophysics. Collectively, results of these several distinct methods help us better understand the spatial extent, size and construction of the ancient mortuary features at the Collins site and situate it within a broader cultural landscape.

**Remote Sensing**

**Is the Relationship between Surface and subsurface temperate is a key for Archeological studies?**  
*Seyed Kazem Alavipanah*

Estimating land surface temperature (LST) using thermal remote sensing data in one hand and subsurface temperature (SubST) by contact measurements in other hand are very important in some environmental studies. However, SubST has not been widely focused especially base on remote sensing data. Recent studies show that depth temperature can be retrieved by using surface temperature data. It is well known that digging is a common way for recovering things produced by ancient cultures that can provide important information about the past cultures. However, digging is destructive and as an archaeological site is dug up it is systematically destroyed and we need some information before digging. Fortunately, archaeologists now can use the benefit of remote sensing data that is a non-destructive way for obtaining information from archaeological sites. Therefore using subsurface data is helpful from many standpoints, One of which that is so critical in archaeological studies is detecting and discovering of buried structures. This study focuses on retrieving SubST by using satellite data. Regarding to material thermal properties, thermal and spectral signature and emission can be a good indicator for detecting surface and subsurface materials. In the field of archaeological researches distribution of temperature, capacity and thermal conductivity are essential aspects. Some studies have investigated the importance of thermal remote sensing in archeological studies. It is important to search such studies and to direct future research into using novel remote sensing in archeological researches. Furthermore, there is a gap in researches about the capability of thermal remote sensing in retrieving LST and SubST, which may provide valuable information about the
buried cultural relics. Thus, in this research, we investigated the relationship between LST and SubST and related models that can be used in archaeological studies. We showed that LST can be a good indicator for estimating of SubST. Therefore we generally conclude that when we have LST, estimating of SubST is possible and also special thermal anomalies from surface to subsurface may lead us to buried objects.

A Collaborative Multi-Sensor Approach to Interpreting the Landscape at House in the Horseshoe, Sanford, North Carolina

Jacob Turner; Roy Stine; Linda Stine; Stacy Curry; John Mintz; Marty Matthews; Jerry Nave

The House in the Horseshoe is a North Carolina Historic site. During the American Revolution, the house belonged to Whig Col. Philip Alston, and was the center of an armed conflict between Whig and Tory militia groups on July 29th 1781. Since that time, the Alston House has had many owners, each who altered the physical and cultural landscape surrounding it in some way, leaving a multi layered and overlapping complex of historical features. Many of these changes to the Alston house landscape are no longer observable, but can be illuminated through metal detection surveys, geophysical remote sensing, GIS, and 3-D modeling. This research included a controlled metal detection survey with the intent of locating the original Alston house fence line and any spatially discrete artifact concentrations. This split rail fence was used by David Fanning and his Tory militia as an attack position during the House in the Horseshoe conflict. To examine this problem, the team utilized the expertise of the Old North State Metal Detectorists, an ethical metal detecting club that we have worked with in the past. The research project also sought to locate the underpinnings or cellar of the Alston house kitchen, and the remains of the soldiers that, according to oral history, were interred “on the brow of the hill, a few rods from the house” (Caruthers 1854). This portion of the research was conducted using Ground Penetrating Radar (GPR), a magnetic gradiometer, historic aerial photography, total station mapping and GIS. The initial GPR and gradiometer surveys are providing the foundation for further research at House in the Horseshoe. Currently, this North Carolina historic site is the focus of a study examining the effects of soil moisture on cultural features imaged with GPR, and fusion of multiple geophysical instrument datasets to improve the accuracy of feature counts and landscape interpretation. In addition, there is a focus on the creation of georeferenced 3D models to place historic maps, aerial photography, and geophysical surveys of hidden subsurface features in a current context, in order to visualize faded cultural landscapes of the past.
Virtual Reality and Cyber-Archaeology

A methodological approach for the 3D reconstruction of the medium Tiber Valley landscape in the Orientalising period

Eva Pietroni; Augusto Palombini; Antonia Arnoldus-Huyzendveld; Marco Di Ioia; Valentina Sanna

The paper discusses a multidisciplinary methodology for the 3D reconstruction of the hypothesized ancient landscape along the Tiber Valley North of Rome, as part of the CNR-ITABC Tiber Valley Virtual Museum project (2011-2014). The area North of Rome, crossed by the ancient consular road via Salaria, has been taken in consideration. The investigation is carried out at different resolutions, from the whole territory to some specific sites.

Final output of the project are multimedia and VR applications for museums in Rome and in the territory, mobile applications for communication needs and a website including narrative contents and methodological studies for an experts audience.

The project follows a multidisciplinary approach to the study of the landscape considered in its several components, geological, natural, historical, archaeological, anthropological, evocative, and symbolic. Integrating bottom-up and top-down approaches, we reconstruct the landscape evolution through the time: geological transformations from 3ml up to 12.000 years ago. The orientalising period (VIII - VII century BC), which this paper focuses on, is particularly important for the growth of the first urban centers. We propose a complete methodology to simulate the ecosystems and the soil use in the past, from data collection and data acquisition on the field through integrated technologies, to GIS elaboration up to the creation of realistic 3D representations.

For the creation of the ecosystems the archaeological map and the land unit map were the starting points. The latter was useful to define the soils composition and their attitude to host specific ecosystems, both natural and cultivated by the man. These data have been combined with demographic analyses in order to define the areas influenced by the presence of human settlements and activities.

A specific methodology has been followed for the buffer creation, considering several factors in relation with the geography and geomorphology of the territory, the distance of the lands from the infrastructures, the economic model, the technological level, the daily need of food and the potential movement of the population in the daily conduction of their work. Each of these factors has a certain proportion of importance in relation to the others, and this relation can change through the different historical ages. For the characterization of the cultivations and vegetal species we were supported by the studies about alimentation and food in the past ages existing in bibliography and by other information from pollen analyses or archaeology.
On this base, from a color map, a 3d scenario has been elaborated in Vue. In our approach 3D representation is fundamental for enhanced learning as in a 3D environment we have multiple possibilities of analyses and interpretation. Moreover 3D is a scenario to tell stories on scientific basis, producing a greater conceptual and emotional impact.

The present work represents a proposal of generalizable formalized model for the landscape reconstruction through time, taking into account the various economic and social models of different civilizations.

A Head of Our Times: Re-Imagining the Heads of the Brummer Collection with Real-Time 3D Face Scanning

Amanda Lazarus; Christopher Tralie

The Notre Dame de Paris *Head of a Virtue*, now part of the Nasher Museum’s Brummer collection, has lived many lives. From the time it was set into the cathedral’s north transept, disembodied during the French Revolution, lost to obscurity, and finally reclaimed in the 20th century as an objet d’art, the virtue tells a complex history of ideological, material and taxonomical mutability. These narratives are being actively explored by the authors through the development of a face mapping application that simulates the diachronic material decay of the sculpture through a 3D model taken of the visitor’s face. As such, visitors are brought into direct contact with the sculpture through a shared experience (deterioration) while also partaking in the historical moment. Moreover, the application of 3D technologies in conjunction with the decay simulation provides a 4D spatiotemporal visualization of the life of the *Virtue* that carries didactic opportunities that further bridge the divide between more traditional approaches to the arts and sciences.

The technical impetus for this project originates in the 3D face recognition studies that have proven texture to be far more essential to geometry for human face perception. Under this scheme, it is possible to re-texture a 3D model of a face for it to resemble another. In our current pipeline, the museum visitor’s face is captured and extracted from a Microsoft Xbox Kinect scan with the help of the 3D face tracking software in the
Microsoft Kinect SDK. A surface is extracted from the point cloud via Delaunay Triangulation and is then aligned to the *Virtue* via Iterative Closest Points. The matching of the scan to the statue is subsequently refined with Generalized Multidimensional Scaling, which optimally stretches and compresses facial features to minimize changes in the geodesic metric on the face. When the resultant texture is applied to *Virtue*, the statue fragment is shown to resemble the person who was scanned. An accompanying timeline punctuated with historically relevant processes of decay—such as the iconoclasm of the French Revolution—will further ground the historical component of this project. The project is an interdisciplinary, collaborative initiative supported by the Bass Connections Fellowship and is intended to challenge both researchers to reach beyond their respective fields, Engineering and Art History.

The “Livia’s Villa Reloaded” project

*Eva Pietroni; Claudio Rufo; Massimiliano Forlani*

Livia’s Villa Reloaded is an innovative virtual reality installation dedicated to the Villa Ad Gallinas Albas, which Livia Drusilla took as dowry to the Emperor Augustus when she married him in the first century BC. This archaeological site is located on a great hill at Prima Porta, at the ninth mile of the via Flaminia, a very important Roman consular road built at the end of the third century BC to connect Rome to Ariminum (today Rimini). Starting from digital acquisition on the field through integrated technologies, both the archaeological landscape and the actual site have been modeled in 3D, together with the reconstruction of how this context could have been in the past, in particular during the Augustan age. The 3D scenarios have been implemented in a Virtual Reality application using mid-air gesture based Interaction. The installation introduces a novel approach in combining different media and languages: real time exploration, cinematographic paradigms, and virtual set practices. The installation has been presented and opened to the public at the end of March 2014 in the Musem of Diocletian’s Baths in Rome.

In the system we distinguish the following 3D cyberspaces:

1) The observable archaeological landscape, showing the site as it is today, acquired through integrated technologies;
2) The potential ancient landscape, based on the interpretative and reconstructive hypotheses supported by the critical study of decorative fragments, bibliographic and iconography references, typological comparisons with similar Roman buildings
3) The hybrid-augmented landscape, consisting in the simplified overlay of 3D reconstructed ancient structures on the contemporary archaeological space.

The 3D representation of the space is the starting point, from which we develop an efficacious communication project. Real time interaction through natural interaction interfaces, combination of different media and virtual storytelling are fundamental
elements able to create an experience, stimulating the user's curiosity and motivations, his perceptive and interpretative faculties.

It is fundamental to find a good compromise between freedom of exploration, easiness of the interfaces and possibility to guide the public during the learning process, giving progressive objectives and stimulus in order to make them not disoriented in a such complex world. Moreover the placement of the installation inside a museum requires engaging the public for a reasonable time, not too long, with the best communicative and learning impact. Therefore every media has been employed to give its best potential.

Techniques and Applications for a virtual Simulation of the agora of Segesta

Riccardo Olivito; Emanuele Taccola; Niccolò Albertini; Daniele Licari

The aim of the paper is to illustrate the work of an interdisciplinary team composed of young archaeologists and researchers of the Scuola Normale Superiore (Laboratorio di Scienze dell’Antichità and DreamsLab) and the University of Pisa (Laboratorio di Disegno e Restauro of the Dipartimento di Civiltà e Forme del Sapere). The synergy between these centres has recently allowed a more articulated 3D simulation of the agora of Segesta. Here, the excavations of the Laboratorio di Scienze dell’Antichità discovered the impressive remains of different buildings and especially a huge stoa, whose first monumental phases date back to the Late-Hellenistic Period. First of all, the paper illustrates close-range photogrammetric methods used during the fieldwork. More specifically, terrestrial and aerial Structure from Motion (SfM) procedures were tested, in order to monitor, document and record the different phases of the excavation activity (layers, findings, wall structures), and to create a reality-based 3d model of the whole site. Given the considerable size of the area, the use of a UAV platform was indispensable for the complete coverage of the agora. The main goal of this documentation methodology is to reduce as much as possible the distance between the phase of data-entry (bottom-up) and the phase of validation, query, processing, understanding and sharing (top-down). The second part of the paper is dedicated to technical explanations of the implementation and use of the 3D models within the CAVE (Cave Automatic Virtual Environment) at the DreamsLab and on wearable devices. On the one hand, the opportunity to visualize the 3D reconstruction of the agora of Segesta, especially within the CAVE, could have a great impact in terms of data dissemination and outreach. Besides, one of the goals of the project currently running at Segesta is to expand the 3D simulation, which is now available only within the CAVE, to wearable devices to be used on-site. On the other hand, the photogrammetric coverage and monitoring of the fieldwork activity allows to simulate within the CAVE the whole archaeological investigation, to go over the different phases of the excavation in a more rapid and accurate way, to get information (measurements, distances, position of the
finds) which could have been ignored during the fieldwork, and to verify, even ex-post, issues not correctly documented during the field activity. The opportunity to physically interact with the 3D model of the agora, makes it possible to drastically increase the level of affordance between scholars/viewers and 3D simulation, and to verify with a completely new approach issues which can be hardly investigated by using 2D models (e.g. physical and spatial relations between objects and monumental context, internal and external visibility, relation between open and closed spaces, lighting inside the building). These topics can be now fully investigated through an ‘immersion’ in the simulated model of the agora of Segesta.

The Regium@Lepidi 2200th Project

Maurizio Forte; Nevio Danelon

The Regium@Lepidi Project started in 2013 as a collaboration between the Duke Dig@Lab and Lions Club Reggio Emilia Host-Città del Tricolore. The project aims to study and virtually reconstruct the ancient Roman town of Regium Lepidi after 2200 years since its foundation. This initiative entails the definition of new methodologies of digital documentation of the urban landscape as well as the implementation of a virtual environment for the general public of museums, envisaging new perspectives on cultural heritage dissemination and virtual exhibit design.

The initial stage of the project involved data collection, GIS mapping and interpretation of the available archaeological documentation in order to draw up a potential urban layout relating to the roman phases of the city evolution. Vector features (points, lines and polygons) were traced after having digitized and georeferenced the drawings. A
detailed Digital Terrain Model of the present landscape was also generated from LiDAR data. Image-Based Modeling (Computer-Vision) techniques have been employed to digitize a set of Roman artifacts, whereas the foundations of a monumental basilica – unearthed in the basement of the Credito Emiliano headquarters – was laser scanned. Digital models provided a basis for a virtual anastylosis of the architectural elements while the remaining foundations allowed some of the main forum buildings to be accurately located. Notwithstanding the work carried out on the site, lack of evidences for most of the other buildings present in Regium Lepidi, was one of the main issues faced for the comprehension of the ancient city plan.

Therefore, an evocative approach was adopted and procedural modeling for the urban area proved convenient in order to bridge the gap between scientific uncertainties and the need of a detailed 3D environment for a real-time simulation. GIS vector features that refer to the Roman street grid (centuriation) provided the input data for the procedural generation of the urban tissue in CityEngine, especially for residential blocks (insulae), while prominent buildings (temples, basilicas, theaters) were manually modeled. Specific urban scenarios were prepared in Unity 3D in order to be visualized through immersive virtual reality devices (Oculus Rift) whereas stereo displays can provide a virtual interactive environment allowing the public to get in touch first-hand with the digital copies of the museum artifacts.

Commercial Archaeological Remote Sensing

CASTLE3D - A computer aided system for labeling archaeological excavations in 3D

Hamidreza Houshiar

Documentation of archaeological excavation sites with conventional methods and tools such as hand drawings, measuring tape and archaeological notes is time consuming.
This process is prone to human errors and the quality of the documentation depends on the qualification of the archaeologist on site. Use of modern technology and methods in 3D surveying and 3D robotics facilitate and improve this process. Computer-aided systems and databases improve the documentation quality and increase the speed of data acquisition.

3D laser scanning is the state of the art in modelling archaeological excavation sites, historical sites and even entire cities or landscapes. Modern laser scanners are capable of data acquisition of up to 1 million points per second. This provides a very detailed 3D point cloud of the environment. 3D points clouds and 3D models of an excavation site provide a better representation of the environment for the archaeologist and for documentation. The point cloud can be used both for further studies on the excavation and for the presentation of results.

This paper introduces a Computer aided system for labeling archaeological excavations in 3D (CASTLE3D). Consisting of a set of tools for recording and georeferencing the 3D data from an excavation site, CASTLE3D is a novel documentation approach in industrial archaeology. It provides a 2D and 3D visualization of the data and an easy-to-use interface that enables the archaeologist to interact with the data in both representations. The 2D visualization and a 3D orthogonal view of the data provide cuts of the environment that resemble the traditional hand drawings. The 3D perspective view gives a realistic view of the environment. CASTLE3D is designed as an easy-to-use on-site semantic mapping tool for archaeologists. Each project contains a predefined set of semantic information that can be used to label findings in the data. Multiple regions of interest can be joined under one label. Further information such as color, orientation and archaeological notes are added to the label to improve the documentation. The available 3D information allows for easy measurements in the data. The full 3D information of a region of interest can be segmented from the entire data. By joining this data from different geo-referenced views the full 3D shape of findings is stored.

All the generated documentation in CASTLE3D is exported to an XML format and serves as input for other systems and databases. Apart from presenting the functionalities of CASTLE3D we evaluate its documentation process in a sample project. For this purpose we export the data to the Adiuvabit database (http://masswerke.de) where more information is added for further analysis. With this information the Harris matrix is created and evaluated. The documentation process is compared to traditional documentation methods and it is shown how the automated system helps in accelerating the documentation process and decreases errors to a minimum.
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