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WHITE Paper for NEH Start-Up Grant - HD-51297-11

Real-time 3D Archaeological Field Recording: Development of an interoperable open-source GIS data entry system.

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- Name of grantee institution, California Institute of Telecommunications and Information Technology (Calit2), University of California, San Diego
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Narrative Description:

- Project Activities

This project has developed and field tested a real-time 3D data recording interface called ArchField for on-the-field archaeological excavations. The software has been streamlined to make it easily adaptable to different archaeological projects using different time periods, contexts, and recording nomenclature. In 2011, this open-source, OS independent, web-based GIS application called ArchField was developed and tested in various excavation settings in Jordan spanning sites from the Early Bronze to Islamic periods. The major activities that occurred during the grant period include development of direct communication with Total Stations and/or several GPS units to acquire and store real-world coordinates, automated creation of Structure-from-Motion (SFM) 3D architecture models from DSLR cameras, automated integration of SFM and LIDAR Scans in CalVR, user-friendly GUI interface designed to rapidly streamline the recording of archaeological data in the field, server based storage using PostGIS on PostgreSQL (CouchDB for iOS), real-time recording and conversion of data to multiple output formats and projections, rapid conversion tools for export and import of data into different formats, synchronization across multiple database servers, dynamic labeling and symbolization of daily recorded artifacts/loci, automatic generation of field top plans and final maps, and auto-generation of labels, barcodes, and QRcodes. At its current state ArchField is fully functional with all OS's through its web based version, and development of a standalone iOS version (for the iPhone and iPad) was started at the end of the granting period.

A number of methods were used to publicize the efforts of the project. Upon receipt of the NEH reward in March a small new report was released (http://www.antiquity.ac.uk/projgall/smith331). In May 2011, a one week workshop on *ArchField* was conducted with the Department of Antiquities of Jordan's survey department who are tasked with all digital archaeological recording conducted in the country. Concurrent with the excavations in the fall, N. Smith presented on *ArchField* at the American Society of Oriental Research Annual conference. In February 2012 a three day workshop was hosted for fellow American archaeologists at UCSD/Calit2 and a follow up workshop at the Department of Antiquities Department in Jordan. A short publication on *ArchField* was published for the Antiquity Project Gallery to make known the research to a broad audience of archaeologists and the online public (Smith et al. 2012). A second more technical article will be submitted to ACM detailing the visualization side of *ArchField*. Finally, a website (http://adaa.ucsd.edu/ArchField/)was created to publicize the project and track its current development.

- Accomplishments

The core objectives proposed in the NEH Startup-grant were met during the granting period. In the first three months of receiving the NEH grant, a number of the programming challenges were resolved and training of the various archaeological project staff in the techniques employed occurred. During this period time was invested in

streamlining of ArchField's interface, providing greater control to the web-based access of the key features of the program, and resolution of distinct challenges involved in developing a data entry program for differing archaeological projects. The programming syntax was refined, new recording features/functions were created, and several hard-coded aspects of the program were rewritten into a setup 'wizard' application. During this period the proper installation and evaluation of application compatibility between the various projects' digital recording equipment was conducted. During the summer of 2011 funding from the NEH grant enabled the project to hire an undergraduate intern to work with the project directors to fully integrate ArchField into CalVR (an opensource alternative to OpenCover). This period was also invested in standardizing the PostgreSQL database for various projects. As part of ArchField's integration a C++ based middle ware program called ArchInterface was created (see below and Appendix C). In fall 2011, ArchField was tested in Jordan in various excavation settings spanning sites from the Early Bronze to Islamic periods. A new objective added to the project at the end of the field testing was to integrate ArchField with the iPad to facilitate field recording. Although ArchInterface was developed to connect Matlab and statistically based programming languages to ArchField there was not enough time to complete this process, but is planned to be implemented the following year. The workshops conducted in the beginning of 2012 and the publication resulted in generating interest by a core group of collaborative projects working in different regions but implementation of the beta testing was postponed until this following year when resources can be devoted to the support and dissemination of the project to other projects. Finally a wiki based user manual still needs to be completed to further assist projects in the implementation of ArchField.

- Audiences

The project attracted a large audience of primarily archaeologists, students working on archaeological projects and researchers in the fields of computer science and computer vision. Specifically for archaeologists interested in using ArchField, requests to become beta testers came from a large geographic reach including both projects based in the United States focusing on various regions of the world as well as projects from the UK, Israel, Italy, Saudi Arabia, and Holland. There are currently 32 beta testers involved in the ArchField project from various institutions located in the regions mentioned above.

- Evaluation

Funding from the 2011 NEH Digital Humanities Startup Grant enabled *ArchField* to be extensively tested and evaluated during the fall of 2011 at various sites in Faynan, Jordan. These sites dated from various different periods and with drastically different artifacts, architecture, and stratigraphy. The evaluation test-beds allowed the tweaking of the software to address requests of the excavators and develop many new features not originally planned. ArchInterface and ArtifactVis were also invented to meet the visualization and research needs generated by *ArchField*. In order to build greater interest in the project, a website was created for *ArchField* and provided contact information for those interested in Beta-testing the current prototype (http://adaa.ucsd.edu/*ArchField*). In May 2011, a one week workshop on *ArchField* was conducted with the Department of Antiquities of Jordan's survey department who are tasked with all digital archaeological recording conducted in the country. The department's Archaeological surveyors were

invited out to Showbak, Jordan where they were trained on the software and they had the opportunity to evaluate it and provide input on how to make it more user-friendly for non-native English speakers. Concurrent with the excavations in the fall, N. Smith presented on *ArchField* at the American Society of Oriental Research Annual conference. In February 2012 a three day workshop was hosted for fellow American archaeologists at UCSD/Calit2 to evaluate the software hands-on and make suggestions for its future use on their projects. A short publication on *ArchField* was written specifically for the Antiquity Project Gallery to make known the research to a broad audience of archaeologists and the online public (Smith et al. 2012). *ArchField* has now undergone several major revisions over the past year through field testing and evaluation and the NEH startup grant has allowed the execution of a beta version that is available to other archaeologists interested in using it on their projects.

- Continuation of the Project

Continuation of the ArchField project and more extensive beta testing is planned over the course of the next two years through funding from University of California, San Diego Calit2 and upon success of receiving a follow up NEH implementation grant.

From the experience of developing *ArchField* under the previous NEH startup grant it became apparent that the movement towards tablets over laptops is most ideal in the field. Primarily the ability to use multi-touch screens and accelerometers to visualize, zoom and rotate as well as naturally enter data. It frees the registrar from a desk and allows them to record data as they walk around the site. An untethered wireless connection to the total station or GPS is also fully possible with the modern radio technology in tablets (e.g. Bluetooth and WiFi). Most important the data entry is much more fluid and intuitive than what is possible with personal computers (i.e. laptops). At the end of the funding period, the porting of *ArchField*'s code to function in a web based environment on tablets was started, but one of the major implementations that will be possible through funding of this proposal is to port the application into native code for the emerging iOS, Android and Ultrabook technology which takes the most advantage of multi-touch and user-friendly data entry over traditional laptops, pc's and even ruggedized PDA's used in survey today (See Appendix B for a detailed explanation). Deployment of the software will be much easier as well since these tablets' operating systems have imbedded online marketplaces in which *ArchField* could be downloaded for free and installed and routinely updated without any user effort.

In conjunction with the movement to native code on tablets, would also be the development of code to fully utilize OpenLayers (equivalent open-source version of google maps; see Appendix C) for mapping of data enabling *ArchField* to imbed on the same window the real-time Top Plan map and data entry fields. Currently OpenLayers only functions as a 2D mapping program but it was discovered in the field at certain periods the simplicity of viewing and manually entering data on a 2D plane was much easier and intuitive during data entry. 3D visualization became much more useful after the day of excavation where time could be devoted to fully examine the data recorded. OpenLayers will serve as another alternative to the other open-source 3D visualization software and enable full exploitation of the tablets' and web based version's programming languages.

Further development of Structure-from-Motion technology for archaeology and time-lapsed 3D recording of ongoing excavations will also be implemented. In the previous grant, the streamlining of SfM code was conducted to improve its resolution, accuracy and compatibility for archaeological use. This work has now opened the avenue to easily capture 3D models of site architecture and excavation levels on a daily basis. Further improvement of this technique will enable a more accurate and detailed method of on-going 3D capture of daily excavations (see Appendices C for current technique and details). The disadvantage of total-stations and GPS for archaeological recording is that their rate of capture enables only artifact positions and locus boundaries to be recorded. Although SfM has a larger measurement of error then these techniques, it captures millions of points providing the ability to reconstruct excavation surfaces and architecture which do not require the same level of precision. It is vastly more accurate than architects' plans of the architecture, section profiles of bulks, or measurement of surface layers which still allow room for an amount of subjectivity and error. In essence, SfM provides an essential context from which all the artifacts and loci recorded using *ArchField* can be situated. Further development of SfM would include designing recording methods and programs to integrate, auto-scale and geo-reference essentially time-lapsed 3D capture of a site's ongoing excavation. This will enable the tracking of the actual excavation process, capture all exposed excavation surfaces, and all in-situ artifacts' original positions, orientations, and low-res 3D representations. This has become an essential component of *ArchField* to meet the goal of a total 3D documentation of field excavation.

The full implementation of a more comprehensive 3D GIS beyond what is currently capable in Google Earth, ArcScene, OpenLayers or other GIS programs is planned with possible future funding from a NEH implantation grant. During the initial phases of *ArchField*'s development Google Earth was use as the main visualization tool for the GIS. Although *ArchField* is designed to be compatible with many different GIS visualization tools, Google Earth had the best combination of features to view data in 3D, control how one navigates, dynamically update information, symbolize artifacts and loci, and integrate various other datasets (e.g. geotiff imagery, digital elevation models, 3D objects, and streaming data from map servers). Yet, at the same time, a number of limitations discovered during its implementation led the project to develop its own open-source 3D GIS through a program called ArtifactVis, which runs as a plugin in the open-source visualization tool CalVR (see appendices A-C, for details and figures). The goal is to include ArtifactVis as a main open-source tool to be used on and off the field in conjunction with the data recording portion of *ArchField*.

Along with the need for a program like ArtifactVis, the importance to develop software to serve as a unifying interface between *ArchField*'s datasets, point cloud 3D models, specialized datasets of material culture, complex mathematical algorithms, and query ability of the data also arose out of *ArchField'*s application on the field. An interface was desired to enable access to numerical computing environments with dedicated programming languages (e.g. Matlab, Mathmatica, FreeMAT, GNU Octave, etc) and for researchers to view the results of these analyses from within the 3D visualization environment. The summer of 2011 was devoted to writing this program, which is called ArchInterface. It serves as a gateway for accessing disparate datasets, translating them for various programs, updating and syncing datasets between different

servers, and offloading complex studies to better equipped mathematically based programs such as Matlab and Python (see appendix C for details and figures). ArchInterface runs both on local clients and remote online servers. ArchInterface has become an essential component of *ArchField* that with further development has the potential to enable a more extensive collaborative research between different projects and harness the power to not only visualize data in various systems but also analyze it without having to leave the 3D GIS environment.

An emerging need discovered through discussion with other archaeologists and its application in field excavations was that its integration with RTK GPS would be the perfect match. However, RTK GPS units are still currently far out of the price range of most archaeological projects. Yet, the technology behind RTK GPS units is still basic trigonometry. The primary limiting factor has been the methods to synchronize two GPS receivers for real-time tracking and correct the satellite measurements for sub-centimeter accuracy. The versatility of *ArchField*'s design would enable the integration of open-source RTK GPS libraries into its recording routine. Therefore, with remaining funds from the previous NEH grant and further support through UCSD the development has already begun for an open-source RTK GPS by the Calit2/UCSD IGEERT program as a key aspect of graduate student Matt Vincent's research. Through further NEH funding it will be possible to fully implement the prototype GPS unit as another alternative for recording in the field with *ArchField* and OpenDig (www.opendig.org).

ArchField is continuing to be developed by the grantee institution after the grant period has expired. The ArchField project has been included as a central project of the NSF IGERT program and resources towards hiring intern students to work with the developing authors has already occurred. Through the publication of ArchField and the ArchField website several new collaborative partnerships have been started through the project's beta program. The beta testing program currently involves several different institutions and archaeological projects that are interested in testing the software on their field excavations. Significant testing and improvement of the software is planned to start in September 2012. We expect through the beta program these collaborations will benefit the future development and continuation of the project leading to its full implementation.

- Long Term Impact

The long-term impact from the ArchField project is a change in how field data is recorded in the field and how it is analyzed and visualized in both research and classroom settings. Currently, ArchField provides an approachable solution to digital recording for any archaeological project as is demonstrated by the interest to adopt ArchField by varying projects seeking different humanities based research goals. We believe with ArchField's full implementation it has the potential of impacting archaeological research as a whole. Second, ArchField's integration with CalVR has already begun to provide a solution for 3D based visualization and analysis of field excavations which can be easily employed in various institutions' research and for classroom instruction. Thirdly, the programs and interfaces developed to handle archaeological documentation are applicable to various other fields including art, architecture, ethnographic research, and applied anthropology. Finally, ArchField's success and the new demands it put on data storage and management played a big role in the grantees department being adopted into the UCSD library digital records project.

- Grant Products

During the course of the project, ArchField's development was published for the Antiquity Project Gallery to make known the research to a broad audience of archaeologists and the online public (Smith et al. 2012). A second more technical article will be submitted to ACM detailing the visualization side of *ArchField in CalVR and how it interfaces real-time with the archaeological database using ArchInterface*. A third article, will also be published on the techniques used to achieve the high resolution fully merged Structure-from-Motion models and their and quantitative comparison to LiDAR scanning. Finally, a website (http://adaa.ucsd.edu/ArchField/)was created to publicize the project and track its current development. Data collected with ArchField is being offered up through a UC San Diego cyber-infrastructure pilot project to the university and public communities (see - http://rci.ucsd.edu/pilots/index.html .