Title
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Journal
Near Eastern Archaeology, 77(3)

ISSN
1094-2076

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Publication Date
2014-09-01

DOI
10.5615/neareastarch.77.3.0166

Peer reviewed

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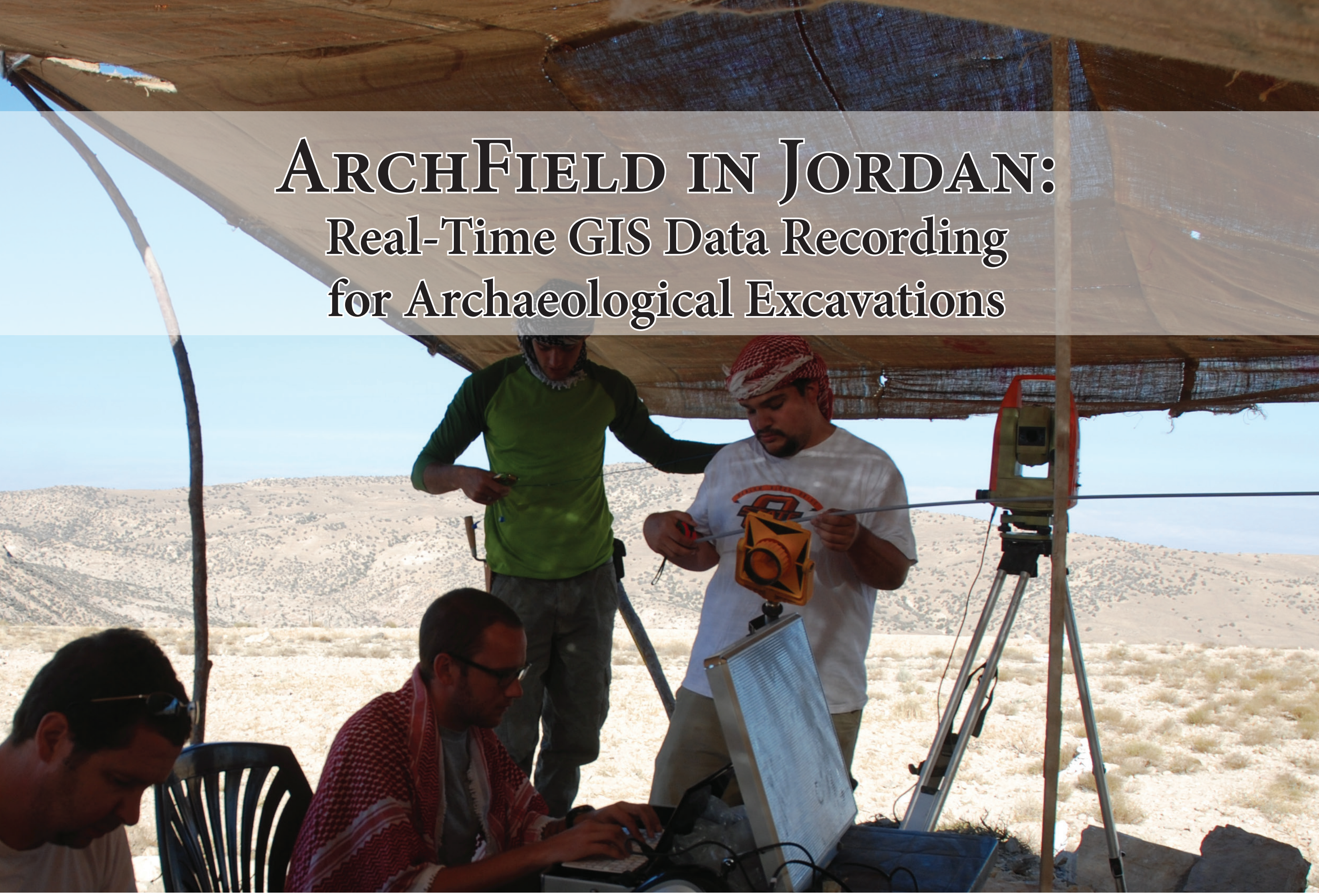


Application of ArchField during field excavations at Khirbat al-Iraq, Jordan. Photograph courtesy of N. Smith.

Neil G. Smith and Thomas E. Levy

Archaeological excavations are the last stronghold of analog recording in this era of digital archaeology. Around the world perhaps at this very moment excavations are occurring where artifacts, architecture, stratigraphic layers, and other archaeological datasets are recorded using only the paper and pen. Every evening after an excavation, supervisors and their volunteers huddle over their illuminated graph paper to convert their written notes and drawings into daily top plans. It is these paper top plans, journal notes, and overstuffed binders filled with printed spreadsheets that much later are meticulously entered into a computer. At this point, long after the season of excavation has been wrapped up, that the drudgery of data entry begins, which with large excavations can take months to digitize, process, and produce data that can be digitally analyzed. As multiple seasons of excavations compound, the delay between field excavation, ability to analyze and to publish increases exponentially.

ArchField is our solution to enable any archaeological project to inexpensively adopt real-time 3D digital recording techniques in their field methods. The software addresses one of the fundamental bottlenecks in archaeology: the curation and analysis of massive datasets recorded over multiple seasons of excavations. ArchField is part of our team's goal to deliver to the field of archaeology a fully implemented solution for high precision data recording, data organization, visualization, and analysis. Over the past three excavation seasons of development and beta testing in southern Jordan, ArchField has evolved under the scrutiny of our field supervisors and student volunteers (Smith and Levy 2012; Smith and Levy, in press). In this article, we present its current evolution and how it has become integrated with our recording schemas, excavation methodologies, measurement instruments, and other 3D digital acquisition tools such as 3D scanning.

A New Era of Digital Recording

Traditional analog methods in archaeology describe artifacts in 3D space by the use of measuring tape and leveling devices. The provenience and description of artifacts or loci are recorded onto a paper spreadsheet and then plotted on graph paper, color coded, and labeled (this paper document is often called a top plan). It is not until a later point in time that these plans may be digitized to create digital top plans or integrated into a GIS. All the rich details of the artifacts or loci are usually entered into spreadsheets and joined as a database much later. The innovation of ArchField is to convert the analog data entry tasks to digital counterparts that save time, lead to greater precision, and seamlessly integrate into GIS applications while still on an excavation. We view ArchField as part of the new era of digital recording that demands real-time recording in the field. To meet these goals the main features we have developed in the software are:

1) Integration of digital survey tools with digital data entry;

2) Streamlined recording and storage of recorded data with high redundancy, reduction of user intervention, standardization, and remote accessibility;

3) On-site analysis tools for detecting recording mistakes, automated registration, real-time GIS visualization, and automatic top plan generation.

4) Combination of diverse datasets such as 3D scanning and aerial mapping into a single GIS software.

Integrating Digital Survey Tools with Data Entry

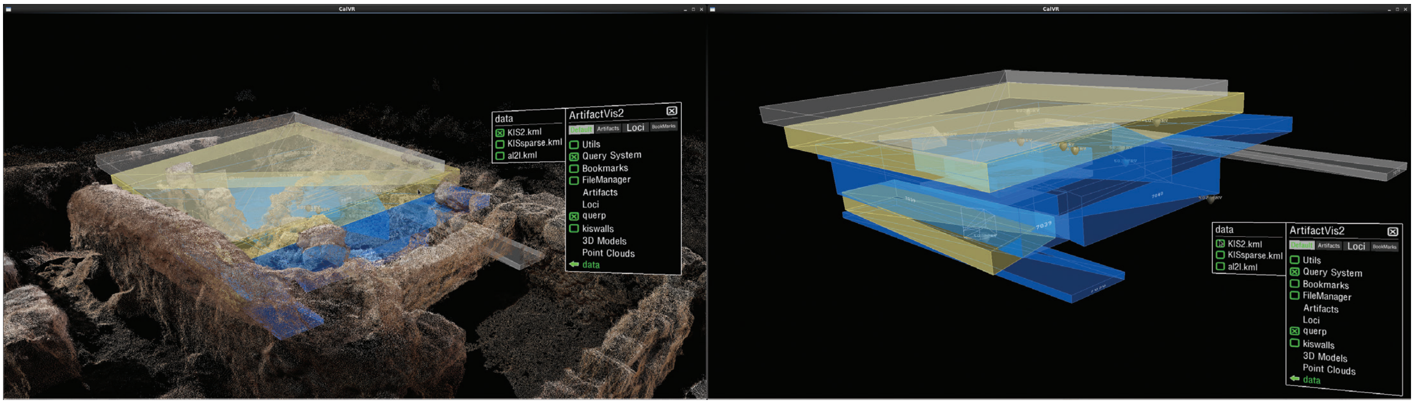
Artifacts and loci are the main elements entered as data in field excavations. Data entry for artifacts consists of 3D recording (x, y, and z) their unique locations and associated metadata (i.e. basket identifier, provenience, date, classification, description, etc.). Most excavations still rely upon imprecise recording methods such as tape measures and dumpy level elevation readings to plot artifact locations on graph paper. We use a Leica total station connected to ArchField to take ±2 mm accurate readings of each artifact's location (fig. 1).[1] As total stations become "old technology" the cost for highly reliable second hand instruments has plummeted. Today one can purchase a used total station on eBay for less than $3,000. When the user presses record on the total station, the measurements are directly read into ArchField. The raw (x, y, z) distance measurement is combined with the known position of the total station and a spatial reference system to project the 3D measurement into a coordinate that can be located on a map or in GIS software.[2] Within the software it is possible to convert the coordinate into any other spatial reference system such as WGS84 Lat/Long as used by Google Earth. The total station connects to the computer running ArchField either through wifi, bluetooth, or serial cable connection. When the coordinate is received from the total station, the supervisor's entered information for that artifact is combined and stored together in ArchField's database. The most critical data entry is the provenience information that describes to which basket, locus, square, and area the artifact belongs. In our excavations the basket number (e.g. 5000…5001…5002) is a sequential number assigned to each artifact.[3] The basket number becomes a unique identifier in the database that can be used to retrieve all the information associated with that artifact, including its coordinate location.

A locus is a distinguishable layer of soil deposit in which artifacts and other features are found. Loci are defined in excavations by the volumetric space of their depositional layer. A locus in three dimensions can be represented as a polyhedron, but typically it is drawn on graph paper as a boundary of the layer's extent. In order to digitally record a locus, we use the total station to take multiple position readings along the physical boundary of the locus. The readings from the total station are automatically connected together in ArchField as vertices of a three-dimensional polygon. As its excavated depth increases we can generate polyhedrons to represent its three-dimensional nature (fig. 2). Each locus is assigned a unique number similar to the basket number assigned to artifacts. The extensive meta-data collected on loci (e.g. sediment composition, density, types of artifacts, associated features, stratigraphic relationships, excavation strategies) using OpenDig are joined to ArchField's locus' unique identifying number (see Vincent et al., this volume).

Figure 1. Example of total station deployed in the field for ArchField in Jordan's Faynan district. Photograph by T. E. Levy.

Streamlining the Recording and Storage of Recorded Data

The supervisor is assisted in taking detailed information on each artifact or locus using ArchField's data entry form. It allows the supervisor to enter all the pertinent information of the artifact



Loci extruded as color-coded polyhedrons representing opening and closing elevations (visualized in ArtifactVis2).The loci shown here are 3D representations of archaeological sediment layers. Image by N. G. Smith.

or locus and have it automatically combined with its 3D location using the integrated total station. To streamline the data entry interface and reduce possibilities of mis-entered data, the application is designed to auto-complete as much information as possible. Once the first artifact/locus is recorded the data entry form remains populated with information that does not change from one artifact to the next. After each artifact is recorded the basket number is incremented to reflect the following unique basket number. Drop down buttons are automatically populated with supervisor's agreed upon descriptions of artifacts or locus characteristics. The general descriptions of the artifacts remain standardized across multiple excavation areas and save the supervisor time from manually re-entering the same description for artifacts. The user only needs to change on a regular basis one or two fields saving time in the long run and preventing typical data entry mistakes. Whenever an artifact or locus is recorded a table appears below the data entry form showing all the pertinent features recorded. This serves as a final check that is used to confirm that all the information was entered correctly prior to moving on to the next recording and allows immediate edits to be carried out if mistakes are found. In this manner, ArchField streamlines the user's entry of data and simplifies user-assisted correction.

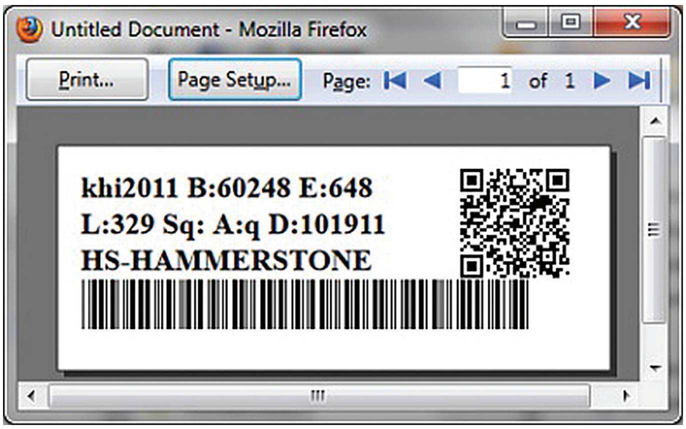


Figure 3. Digitally generated label with barcode and QR code. Image courtesy of N. G. Smith

Additionally, the real-time recording enables the ability to automatically generate printed labels with barcodes for every artifact or locus basket recorded (fig. 3). Once an artifact or basket elevation is recorded a button appears for label printing. When this button is clicked it pulls the information from the table and prints a label with all the important information on an encoded barcode. The printed labels save time for the registrar, eliminate human error, and prevent the label from being misread due to poor handwriting.

Field Deployable Application

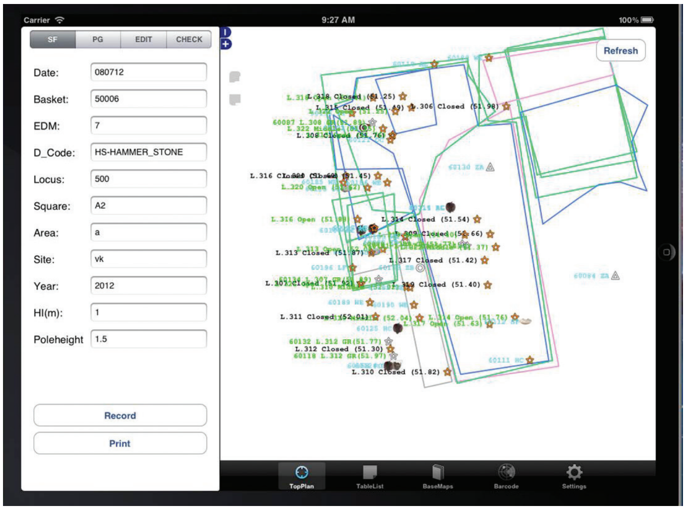
ArchField builds upon a decade of previous methods of digital field recording (Levy and Smith 2007) and has now undergone several major revisions over the past three years as it has been thoroughly field tested in southern Jordan. We employed ArchField at sites with different climatic environments, site functions, and states of preservation. Out of this test bed we have developed numerous versions of the software and experimented running it on a diverse set of computer hardware and operating systems. Currently, ArchField has been designed as a stand-alone web program, iOS app, and standard C++ based program from Windows, Mac OS, and various versions of Linux.

In 2010, we designed ArchField as a web-based version using the combination of HTML, PHP, and Javascript languages (fig. 5). The main advantage of this approach is that it can be run on any operating system with a web browser and the code can be easily changed without a need to recompile. The web-based version has the most minimal hardware requirements and a footprint of less than 100 mb. It can be run on any computing device that can serve a webpage. This means the web-based version can run on a tablet, smart phone, imbedded device, netbook, or standard laptop.

We have recently ported ArchField to run as a native iOS app (fig. 4) and are currently developing an OS-independent C++ compiled version to enable more complex features on Windows-based tablets (fig. 6). The advantage of ArchField as an OS-independent GIS and data entry tool is that it can be deployed on any device rugged enough to be brought out to the field.

Pervasive Digital Storage of Field Excavations

ArchField is connected to our GIS server database so that whether in the field, in the dig lab, or back at the university our supervi-



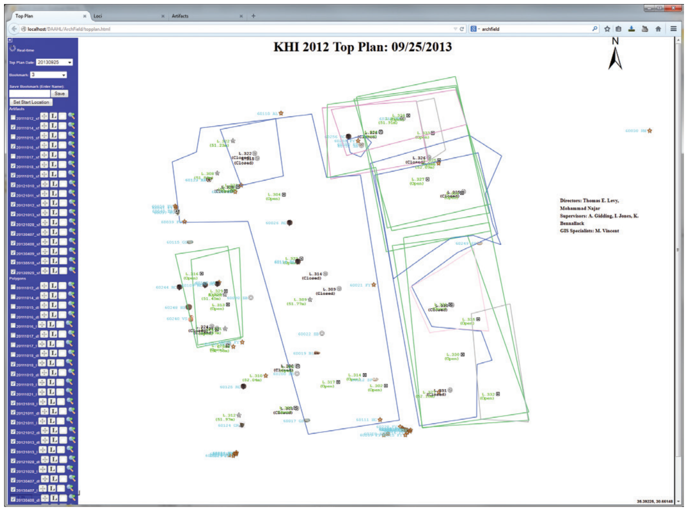
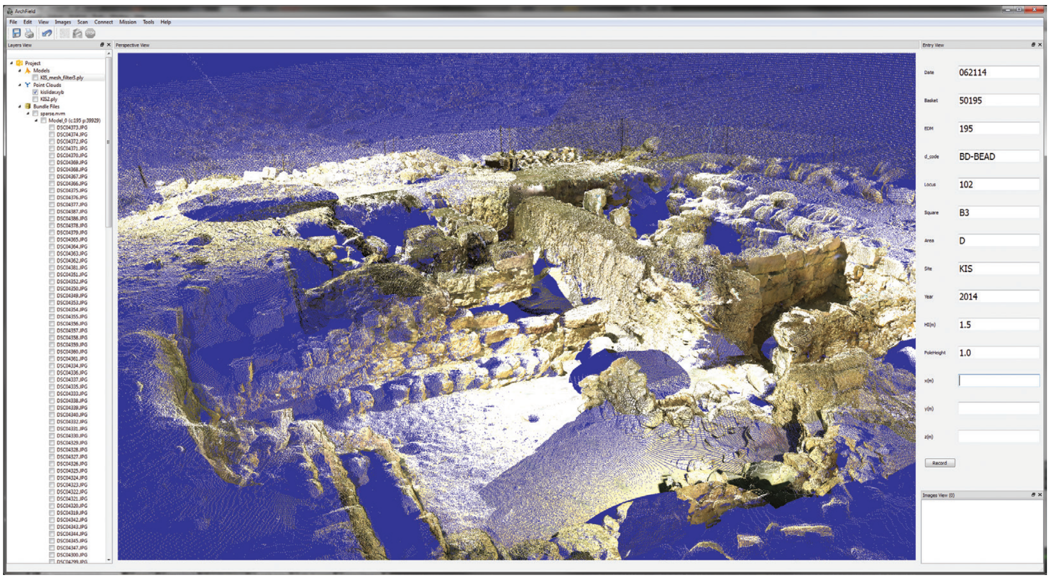


Figure 4 (top left). ArchField running natively on an iPad.
Figure 5 (top right). ArchField web version with OpenLayers integration.
Figure 6 (below). ArchField C++ with 3D LiDAR scan of Khirbat al-Iraq excavations in Jordan. Images by N. G. Smith.



sors and specialists have real-time access to data being recorded in the excavations. We use a SQL database called PostGIS that provides a robust and efficient query system allowing asynchronous spatial queries across a shared network. As data is recorded in the field, it is stored on a local PostGIS server database that then syncs to our field lab's server computer and on a periodic basis to our university's servers.[4] The server database enables multiple users to access the same data in real-time preventing divergent copies of the same database. The database stores spatial information for every artifact and locus allowing ArchField to later query the data and render the results as a 2D or 3D map.

A Publishable Digital Top Plan Straight from the Field

ArchField automatically processes incoming data so that it can be viewed in real-time as a digital top plan (figs. 4–6). Dynamically changing data can be handled so that a top plan's symbology, labels, and colors are auto-generated.

While in the field, the digital top plan allows the field supervisor and registrar to track their excavations as they would on a traditional paper top plan, but with the added benefit of a full GIS. They are able to conduct queries, toggle layers, make quick edits, and zoom in on pertinent features. They see the current day's top plan as it is constructed and can immediately tell whether a locus or artifact was incorrectly recorded. The real-time top plans allow an archaeological project's supervisor to catch mistakes while still in the field, being more in tune with the current process of digital recording, and be freed up to focus on other aspects of documentation after a morning of excavation. Having real-time and vetted top plans by the end of the excavation enables immediate analysis and a direct transition to final publishable excavation plans. As data is recorded in the field a comprehensive and accurate GIS is constructed that can be immediately displayed in virtual museums and for 3D visualization.

3D Recording for Everyone

ArchField is used to generate the ground control points to georeference 3D scans (e.g. LiDAR and SfM) so that the resulting point cloud models can be loaded into the same geographic space as the recorded artifacts and loci. The latest version of ArchField has been rewritten in C++ and uses OpenSceneGraph to efficiently render these point cloud models onto the recorded top plan. Although in its initial alpha stage, ArchField C++ is able to render our most dense SfM models and triangulated meshes on Windows Surface Tablets at full 60 frames per second (fig. 6). Every component of the data recorded is immediately available for analysis and visualization both in ArchField and our 3D visualization software called ArtifactVis2 (see fig. 7; Smith et al. 2013). This has allowed us to continually return to the site to examine its architecture, spatial distribution of artifacts and stratigraphic layers in a fully immersive 3D environment that is connected to the same GIS server that ArchField updates on a daily basis in the field. We have been able to show other archaeologists the excavations and discuss in detail various aspects of the excavation process and theories on its use from across the globe.

Figure 7. ArchField artifacts and loci displayed in same geographic space as SfM and LiDAR scans (visualized in ArtifactVis2). Image by N. G. Smith.

From the ground up ArchField has been designed to streamline the digital recording of spatial and contextual data in real-time. The processing pipeline enables the generation of publishable online maps from the first day of excavation to the last. This technique has enabled us in our own research to digitally present our ongoing research to a large audience of archaeologists on our individual computers, online and in virtual museums. We see our current research as just beginning. We are now working towards the extensive integration of SfM with ArchField to enable daily recording of surfaces, loci, and in situ artifacts to create truly life-like captures of artifacts and their context.

Acknowledgments

This project was funded in part by a National Endowment for the Humanities Digital Humanities Start-Up grant (HD-51297-11), the NSF IGERT TEECH grant (NSF 0966375) where TEL is a Co-PI; and King Abdullah University of Science and Technology. We are grateful to the Department of Antiquities of Jordan, Dr. Mohammad Najjar, and the UC San Diego ELRAP/L2HE projects staff and students.

Notes

1. Currently total stations achieve the highest precision in survey grade measurement even in comparison to RTK GPS systems which have an accuracy of 8.0 mm +1 ppm (horizontally) without post-processing. With post processing it is possible to achieve up to 3 mm +0.1 ppm measurements using static GPS. Post-processing is something that must be done at a later point in time and typically assumes the rover GPS was held in the same position for a longer observation period than as used for RTK GPS readings.
2. The specific coordinate system we use on our excavations in Jordan is Universal Transverse Mercator.
3. On our excavations we create an allotted bank of numbers assigned to the specific area of each excavation. However, basket numbers are assigned in many different ways in different excavations. Although ArchField was setup to employ our recording methodology, we have adapted it to work with other projects such as those that assign overlapping basket numbers that use the combination of the basket with the locus number to uniquely identify an artifact.
4. We have specifically designed our server to be able to sync information to mirrored servers when we have connection. With our lab's 3G internet connection, we can remain synced in real-time to our online server, but in practice we only sync to our remote online servers on a periodic basis to save bandwidth.

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