SiteMap: Innovations in Computer Based Mapping for Archaeologists

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Abstract. Development of computer aided surveying has been an ongoing project at MASCA (the Museum Applied Science Center for Archaeology at the University of Pennsylvania Museum of Archaeology and Anthropology) for over a decade. The surveying software that we now call SiteMap has, in various incarnations, been in use on a wide range of Museum affiliated excavations. Its evolution from custom in-house tool to more generalized system, as recounted here, serves as a case study in the development of technical software. Its adoption for use on a wide variety of sites shows the success of the approach taken. Usability, portability, flexibility, and comprehensibility have driven the programming, providing the project with much greater longevity than similar applications. The particular issues tackled by MASCA, however, are common to anyone wishing to create accessible and long-lived programs.
Keywords: Mapmaking, Surveying, CAD.

1 Introduction: Total Station Surveying

Because of its essential focus on spatial data, archaeological fieldwork historically has placed heavy emphasis on mapmaking. Archaeologists, accordingly, have had great interest in those technological advances that facilitate the creation of their maps or increase the accuracy or functionality of those maps. One such technology which has over the past decade found wide acceptance on archaeological sites is electronic total station surveying. MASCA saw the benefits of this technology early, and has continued to refine its actual, on-site, use.

The commercial software bundled with most data collectors and total stations is quite good for land and construction surveying. However, it is often woefully inadequate for the needs of archaeologists. Though the equipment is the same, the requirements of someone building a skyscraper are very different from those of someone recording a temple in ruins. Archaeological surveying is, at once, simpler and more complex than land surveying. The difference between the two approaches is manifest in two ways:

1. archaeologists generally need a high level of accuracy (i.e., millimeter-level, or in surveying terms, first-order) accuracy across a relatively small area—but though accuracy across greater distances is desirable, it is not critical to human safety or to property law;
2. archaeologists need to attach large amounts of descriptive data to the 3-dimensional coordinates that they record.

In other words, when using commercially-available products, archaeological surveyors are typically burdened by overly complex software that, nevertheless, fails to record all of the archaeologically pertinent data of the objects being surveyed. The effect of these differences is compounded by the fact that many archaeological surveyors have minimal training or experience, and are therefore somewhat prone to make mistakes. On most excavations, therefore, accuracy and efficiency are rarely attained, and year-to-year consistency (despite being highly desirable) cannot be expected. Independently, a number of archaeologists and institutions, MASCA included, sought to remedy these deficiencies by writing their own data collection software for total station surveying.

2 COMPASS: Computer Aided Surveying in Archaeology

The need for uniquely archaeological surveying software was seen at MASCA as early as 1985 when Andrew Weiss began developing the first version of COMPASS (COmputer Mapping Program for Archaeological Sites and Survey) (Weiss 1989). This suite of programs was created primarily as an in-house tool to bring technological improvements to mapmaking on the various ongoing Museum excavations.

The data collection module of COMPASS was a small, simple program tailored specifically for use by archaeologists and written to run on a variety of handheld computers (eventually settling on Corvallis Microtechnology MC-II and MC-V data collectors). Its inter-

face was minimal but functional, and it wrote the survey data to an ASCII text file with a proprietary format that recorded metrical data as well as textual archaeological data.

The COMPASS datafiles would then be uploaded to an Apple Macintosh computer for use by the data plotting component of COMPASS. The use of macro scripts written for a commercially-available CAD package, MiniCad, to plot the survey data allowed COMPASS to take advantage of preexisting, commercial quality solutions for input, display, layers, tablet support, printing, rendering, and general operating system compatibility. In doing so, COMPASS sidestepped the difficulty of creating a good standalone drafting application—freeing the programmer to focus on data collection without denying advanced draftspersons the mapmaking tools that they desired.

3   ForeSight: Object-Oriented Surveying

By 1995, COMPASS had become the predominant surveying software in use on University of Pennsylvania Museum excavations. Its strengths and limitations were adequately revealed through extensive field testing, and a wish-list of new features was compiled by its users. Most critically, its user interface had become painfully archaic, and the limitations of its old programming techniques masked many of its strengths. In order to correct these problems, we decided to rewrite the data collection and data plotting modules from the ground up. A small team of programmers, consultants, and testers—all field archaeologists—set about to rebuild COMPASS. The scope of the resulting changes, we felt, was sufficient to warrant changing the system's name to ForeSight.

At the time, our concerns were with general improvements to usability. We felt that the groundwork laid in COMPASS could be used to create a surveying system that could be profitably employed by even a novice surveyor with rudimentary computer skills on a wide range of sites. Accordingly, changes focused on accelerating the on-site recording of information while concurrently increasing the flexibility of the software. Additional error protection was also added. Our goal was to create a system that could be used competently by a surveyor with only a few days of specialized training prior to actual fieldwork.

At the data collection stage, this goal was implemented by completely rewriting the user interface of the data collection software. In order to lower the learning curve, the program was rewritten to be event-driven, with all available options displayed on-screen and accessible through menus and/or function keys. Furthermore, user defined preset values for commonly used variables (like station coordinates, prism offsets, classes, and subclasses) were also added to streamline onsite operations. We feel that this kind of simplicity, by minimizing confusion and operator fatigue, is critical to producing consistent and accurate results—particularly under the strain of actual fieldwork.

When using the rewritten data collection software, after initially setting up the instrument, the operator only touches the total station to sight on the target. All station settings, azimuth corrections, and offsets are entered into the data collector—which, itself, displays positions in a standard coordinate system consisting of Northing, Easting, and Elevation.[1] Whereas many other systems require that the user press keys on both the data collector and the total station, the ForeSight interface simplified operation and reduced confusion. Likewise, the data plotting software was also simplified by embedding the plotting routines in a template file, improving its error handling, and guiding the user through the procedure.

In light of the many changes we made to the component software, we also took the opportunity to re-evaluate and revise the COMPASS datafile format. The resulting ForeSight datafile format was deliberately developed to be much more readable by humans. Advancements in computer technology enabled us to replace the memory-efficient, but cryptic integer codes used as formatting tags by COMPASS with descriptive text strings. Moreover, a number of new database features were added to the new datafile format. These new features were:

1. automatically-assigned point numbers;
2. user-assigned point names;
3. hierarchical user-defined classes and subclasses;
4. available text annotation.

These new features were supported in the data plotting software through automatic loading of MiniCad's internal database, and contextual plotting of certain predefined objects—marking them visually and providing the mechanism by which searches can be performed on the survey data using MiniCad's built-in filters.

The new datafile format also led to a conceptual change in the way archaeologists using ForeSight viewed their survey data. Rather than recording geometric relationships between existing or projected features, which is the principal concern of land surveyors, ForeSight allowed archaeologists to address their own specific concerns by accommodating 0, 1, 2, and 3-dimensional objects in 3-dimensional space and by linking spatial measurements with archaeological information. As archaeologists, we are principally concerned with recording information about objects revealed in the process of excavation—and utilizing these data for interpretation. In other words, we record survey data about archaeological objects in order to later represent archaeological objects as survey data in our maps. The ForeSight datafile format organizes the surveying data to reflect the way that archaeologists view the objects and features they are recording—as discrete entities in

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[1] NEZ coordinates were found to be preferable to distance and angle measurements because of their easier comprehension by novice surveyors, because of the greater ease with which they are plotted in MiniCad, and because of their easier integration with UTM-based grids.

an existing spatial relationship, not merely as projected points and lines. At MASCA we refer to this approach to survey data as *object-oriented surveying*.[2] While more traditional conceptions of surveying data can be encapsulated by the object method, this method is ideally suited to building site-wide GISes.

By 1999, we had a proven track record that our software and the object-oriented approach do work in the field, on a wide variety of sites. At Copan, Honduras, COMPASS and ForeSight have been used to map architecture excavated in tunnels—a very difficult work environment. At the Etruscan site of Poggio Colla, Italy, ForeSight has become an intrinsic part of the field school component of the excavation. At the Great Temple of Petra, Jordan, ForeSight has been used for planning excavations and for reconstructing and interpreting this complex and unique structure (Zimmerman 2000). At the Deserted Medieval Village of Cottam, England, fine-grained maps of the topographic features revealed, through nondestructive methods, the development of the village plan (Fitts 2002). And at Abydos, Egypt, our software has been used to create maps at a wide variety of scales—from individual structures to the entire ancient landscape (Pouls Wegner 2002).

4 SiteMap: Advantages of Modular Design

The developmental versions of ForeSight generated enough enthusiasm within the Museum and associated excavations that serious consideration has been given to releasing it publicly. In preparation for this we abandoned the working name "ForeSight" and renamed the software SiteMap to avoid a potential trademark dispute. Fortuitously, MiniCad (since renamed Vector-Works) was, at this time, released as a cross-platform application. Thus, with only minor changes to our data plotting script, we gained feature and operational parity, with one set of code, between the plotting modules for both Macintosh and Windows. This benefit would likely never have been realized had the data plotting component of COMPASS, like its data collection component, been a custom-built application.

Until recently, the equipment that SiteMap supported was determined largely by the legacy of Weiss's decisions during his development of COMPASS. Since then, our choices of data collectors and total stations were largely determined by our desire to support MASCA's existing hardware. However, we are now faced with the challenge of expanding the kinds of equipment that we can support—and in doing so, we find ourselves again paying greater attention to the datafile.

In a nutshell, the datafile is a tab-delimited text file containing the database information and Cartesian coordinates of each shot taken. In addition, it contains tags that identify how the individual shots are to be plotted, and whether they are isolated points in space or series of linked points defining, say, the outline of an object. However, no platform-specific or script code is contained in the datafile, thereby ensuring its portability. Tab delimitation (rather than comma delimitation or field length) also ensures that the data can be read by humans and reconstructed in the future.

Because of its straight ASCII format, the SiteMap datafile format exists independently of any particular data collection and data plotting programs. It can be created by any programmable data collector and read by any computer. For instance, we have recently rewritten the data collection software for the more capable and affordable Palm PDAs, and we could without too much difficulty port the data plotting routine to AutoCAD, MicroStation, ArcView, or GRASS with near feature-parity. More importantly, however, we can also accommodate new surveying methods. For example, we have recently incorporated support for NMEA-0183 compatible GPS receivers—the coordinate data from which are output as a SiteMap datafile, and are therefore completely compatible with SiteMap total station data. By respecting the format which evolved over the last decade, we can expect a reasonable degree of continuity, despite the inevitable advances to data collection and data plotting equipment and software. And, as the technology evolves, projects that have been using SiteMap can update their surveying equipment without abandoning, converting, or recreating their previous data.

Furthermore, the datafile itself is both flexible and extensible. For example, though the first version of ForeSight was only capable of plotting objects in two dimensions, later versions of MiniCad render the same, unmodified, datafiles as fully 3-dimensional objects. This was possible because, despite the limitations of early versions of MiniCad, we anticipated later advancements and included 3-dimensional data in the datafile specification. Likewise, though the capacity to record 3D surfaces has only recently been added to the datafile, older versions of SiteMap handle the new object type without difficulty because the datafile specification treats unknown (or, in this case, yet to be defined) object types as in-line comments. Thus, should we choose to implement survey objects or data collection routines that cannot be supported by the current data plotting script, we can expect that they will be usable by later versions of VectorWorks (or even entirely different CAD or GIS software) if they adhere to the specified format, but ignored by current versions. This datafile-centred approach to SiteMap was driven by the needs of ForeSight's early adopters for compatibility with their COMPASS data, and realized by the collaborative approach to sofware development taken by MASCA. And despite the more obvious improvements to the user experience, a well-designed datafile format is the centrepiece of our current efforts.

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[2] We use the term "object-oriented" to reflect the primacy of real-world objects to our surveying methodology. As such, our objects, as digitized abstractions of real-world entities, are more akin to the graphics objects in a computer illustration application than the intercommunicating containers for methods, in the object-oriented programming sense of the term.

5 SiteMap's Future

SiteMap's modular design lends itself to numerous modifications and improvements, and its heavy use suggests constant refinements. Work has already begun on a number of enhancements, and given the available resources, we hope to address each of the following points:

1. improvement of SiteMap's database capabilities, beyond what is currently possible within Vector-Works' internal database manager;
2. improving SiteMap's analytical functions;
3. support of additional object types (such as, for example, volumes and radii).

If possible, we would like to add these features within the framework of VectorWorks and its built-in scripting language, VectorScript. However, we do not rule out the possibility of porting the data plotting script to a full-featured GIS package, which would have database integration and analytical functions pre-built. Improvements to data collection will focus upon refinements to our current adoption of Palm PDAs and GPS data.

The robustness of the datafile (its human-readability, flexibility, extensibility, and consistency), coupled with the deliberate simplifications to the surveying process (error protection, hardware abstraction, and comprehensible interface) have, in concert, given SiteMap (and its predecessors) its great strength and longevity. We believe that the value placed in a comprehensible user interface and well-planned datafile format—developed within a highly collaborative environment with extensive field testing—have led to our project's success. So regardless of the particular enhancements made, we are confident that continued focus on these principles will yield continued improvements to our software.

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