GIS Trainings for Archaeologists

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Introduction

It has been nearly 30 years since the Geographic Information Systems (GIS, hereafter) were first employed for archaeological use between 1979 and 1982 as a part of the Granite Reef Archaeological Project in the American Southwest (Kvamme 1995). Nonetheless, it was only since a series of seminal volumes were published during the 90s (Aldenderfer and Maschner 1996; Allen et al. 1990; Lock and Stančič 1995) that this technology began to prevail among archaeologists for practical use. The recognition of GIS among archaeologists as a practical research tool has not been strengthened enough to be considered as a part of the mainstream of the discipline. Regarding the latest decade, this can be attributed partially to the lack of professional training tailored for archaeologists (Matsumoto 2005). As of 2007, except for a portion of academic institutions, it has been customary practice for archaeology students to take courses concerning GIS and related technologies in the department of geography. Needless to say, because those courses are originally designed for geography majors, the course materials and contents do not necessarily fit our needs. Those courses lack some critical components that are essential for archaeologists. In this paper, I will point out some of the inefficiencies and weaknesses of the current situation and will argue for the need of GIS trainings for archaeologists. My primary aim is to provide the rationale to support establishing a new course for archaeological GIS in our department within the next few years.

What are GIS?

GIS are defined by Green (1990:3) as follows:

> Geographic information systems are essentially spatially referenced databases that allow one to control for the distribution of form over space and through time. They are more than computerized cartography because they provide for the storage, mathematical manipulation, quick retrieval and flexible display of spatially referenced data.

Green's definition corresponds exactly to Marble's (1999:12-13) structural model of GIS consisting of four major sub-systems: (1) Data entry subsystem, (2) Data storage and retrieval subsystem, (3) Data manipulation and analysis subsystem, and (4) Data visualization and reporting subsystem. In addition to these four subsystems, Wheatley and Gillings (2002:11) add User Interface (Figure 1). From commercial ones such as ESRI's ArcGIS to noncommercial GRASS[1] (Geographical Resources Analysis Support System), recent GIS applications have basically the same logical structure of those five subsystems. These subsystems are designed to be interrelated to each other to accomplish intricate procedures for storage, analysis, and display of spatially referenced data in response to a user's commands. As you can see in Figure 1, furthermore, we now have a good selection of data input and output devices compatible with GIS. Flexible data input

[1] GRASS (Geographic Resources Analysis Support System) is a free open source GIS originally developed by the U.S. Army - Construction Engineering Research Laboratory (USA-CERL, 1982-1995), a branch of the US Army Corp of Engineers in Champaign, Illinois. See http://grass.itc.it/ for more information.

and output in cooperation with those peripheral devices is one of the major features of GIS as well.

Geographic data that we deal with in GIS basically link three different types of data: place, time, and attributes. Place is an essential element in geographic information, which is used to plot the objects of interest precisely on a map, whereas time is optional. Attributes are explanatory information assigned to particular places and are subdivided into five different scales: nominal, ordinal, interval, ratio, and cyclic (or directional) (Longley et al. 2001:64). Taking site data as an example, place is the information of site location usually represented by Cartesian coordinates. Attributes are arbitrarily configurable and basically expandable data such as site name, site size, site cluster and associated canal system, linkage information to artifact inventories in external database, and so forth. In any case, this data structure consisting of three fundamental data types operates quite similarly to that of traditional recording system of site location on maps, linked to references of attribute information (Maschner 1996; Wheatley and Gillings 2002).

The data layers are stored in one of two formats as vector or raster data. The vector data model is based upon the "discrete object view" where geographers see the world as an empty space occupied by objects with well-defined boundaries, which are distinguished by their dimensions and represented by points (vertices), lines (sets of vertices connected by precisely straight lines), and polygons (areas enclosed by a series of straight lines connecting vertices) (Figure 2). This concept of space is quite similar to that of archaeologists before postprocessual interventions. The raster data model, on the other hand, is based upon the "field view" where geographers consider the world as a continuous surface, which is divided into a fine mesh of gridded cells with a series of properties or attributes assigned.

For the purpose of display and analysis, both location and attribute data are organized into thematic layers, accumulated one over another (Figure 3), and manipulated for further analyses (Maschner 1996:2; Wheatley and Gillings 2002:25-28). These thematic layers, for example, may involve such natural and cultural features as topography, soils, lithology, microclimate, hydrology, roads, vegetation types, and archaeological site distribution. The ability to construct new data layers from those already associated with maps is one of the most important features of GIS. Such sidebar layers may include aspects, slope or grade, view, and so on (Maschner 1996:2).

Merits of GIS for Archaeologists

GIS have various capabilities that are useful to archaeology. One of the most important benefits from an archaeological application of GIS is that GIS software alleviates a huge burden on making distribution maps and avoids a series of human errors common in hand-made maps (Wheatley and Gillings 2002:18). Traditional manual mapping methods have never allowed efficient data addition, modification, and deletion. Quite unfortunately, there was no way but to sweep the slate clean. With GIS, however, archaeologists need no longer modify their maps themselves. All they have to do is directly modify the data in thematic layers. The modification will automatically be reflected on the map of interest. In addition, the combination of data overlay can be changed very easily according to need. This was not allowed by the conventional manual mapping either. Thus, the timesaving technology provides archaeologists with much more time to spend for analysis and interpretation.

Secondly, GIS virtually have no limit on scale and allow us to freely zoom in and out. This means that you can move back and forth to display, analyze, and print maps that are different in scale from continental level down to single grid level of excavation unit. This quasi-scale-free data management structure is completely compatible with the multi-stage spatial conception of conventional settlement pattern study and with the ongoing paradigm shift into interregional or macroregional researches (Balkansky 2006).

Thirdly, GIS are compatible with various data sources and external analytical software. Major data sources involve remotely sensed data (e.g., aerial photography and multispectral satellite imagery) and digital survey equipment (e.g., Total Station and GPS). You can also import traditional hardcopy maps by digitalizing them through the use of scanner and digitizer. In the past several years, the role of the internet has become very important. Various types of geographical and attribute data can be purchased or downloaded free from digital archives on the World Wide Web. Imported data are organized and processed for subsequent spatial analysis and decision making. Although GIS come equipped with standard analytical tools, those data can be transferred to external analytical software for more vital capabilities.

The flexible compatibility of data integration in GIS further helps to cultivate sustained interests of archaeologists in multidisciplinary collaborations. As the role of GIS as a comprehensive archaeological database is further developed, much wider variety of data sources will be integrated into the spatio-temporal overlays of GIS. Aside from conventional base map components such as topography maps and remotely sensed data, they involve geophysical and geochemical data (e.g., magnetometry and Gas Chromatograph/Mass Spectrometry) and subsurface information sensed by Ground Penetrating Radar (GPR) (Campana and Francovich 2003; Kvamme 1999; Shimada et al. 2003).

Major Analytical Methods of GIS Applications

The concepts of space and landscape have gradually changed all along the history of archaeology. In the early 1980s when GIS were first introduced into archaeology, there were two opposing views: the processualistic spatiality (space as non-problematic abstract backdrop and the image of landscape as a palimpsest of material traces), on one hand, and the postprocessualistic backlash against it, on the other. Similarly, GIS applications were also split broadly into two separate directions. Some archaeologists who kept going on their old track began to pursue locational modeling on the basis of conventional settlement pattern study and regional-scale site databases (Westcott and Brandon [eds.] 2000). Those who were oriented to more postprocessualistic approaches, on the other hand, sought to reconstruct past environment for the ultimate purpose of reconstructing past landscape.

Predictive Modeling

Due to its substantive use in many research projects, predictive modeling has become a defining feature of GIS in archaeology, since it emerged in the 1980s. The purpose of this type of modeling is to predict the probability of the occurrence of an archaeological event in a given locus through statistical techniques such as discriminant analysis or logistic regression. For its cost-effective nature, predictive modeling was favored particularly by CRM research and land development programs in the United States. Through the modeling studies, researchers could address potential locations of archaeological sites without field surveys and thus more probably keep themselves away from a threat of destroying them. In other words, the modeling study assumed a vast unsurveyed area. Earlier predictive models came to be criticized because they relied heavily or exclusively on environmental variables; however, in the 1990s the modeling studies went beyond mere locational prediction based on topographic features and began to attribute the spatial distribution of archaeological remains to non-environmental variables (Allen 1996; Hasenstab 1996). It is likely that predictive modeling will become a more reliable tool for spatial analysis in GIS through some refinements, such as a thorough consideration of both environmental and cultural factors and their interaction.

Postprocessual Orientation

Maschner (1996:5-13) sketches out several spatial analyses available for GIS-based archaeology. Those involve cost surface analysis, viewshed analysis, optimum path analysis, site catchment analysis, boundary definition analysis, and so on. The most attractive of these for archaeologists may be viewshed or line-of-sight (LOS) analysis. This 3D-GIS-based approach helps archaeologists examine the actual view of prehistoric people and explore their perception of landscapes, putting larger foci on social and cognitive characteristics of prehistoric human behavior.

Wheatley (1996), for example, is concerned with how prehistoric people in Wessex, England perceived their landscapes and with the spatial scale of that perception. By adopting multiple viewsheds from specific points, Ruggles and Medyckyj-Scott (1996) attempt to examine the relationship between stone monuments and astronomical phenomena on the Isle of Mull, Scotland. Furthermore, Madry and Rakos (1996) employ optimum path analysis as well as viewshed analysis to examine the relationship between Celtic hillforts and roads in the Burgundy region of France. They argue a strong correlation of these roads with visibility from the hilltop defenses.

For their basic concept of space, GIS are inherently more suited for processualistic research issues. Thus, priority is now being placed on the search for more postprocessual applications beyond viewshed analysis. In order for archaeologists to pursue the experiential phenomena of past people such as perception and experience, it is essential to make efforts to reconstruct the same set of material relationships in which the people found themselves in the past. Postprocessualistic approaches should not be thought of as an antithesis to the preceding processualistic counterparts, but considered as logical outgrowth of the processualism. As a consequence, many multidisciplinary research endeavors are now aimed at reconstructing paleoenvironment for the ultimate purpose of reconstructing past landscape.

Limited Availability of Appropriate Training

As described above, it is obvious that GIS and related peripheral techniques hold the promise for future archaeological research. I believe that I could gain your understanding of the merits from the archaeological application of those technologies. Nonetheless, since the 90's the use of GIS has not been prevailed among archaeologists well enough to earn support from the majority of the discipline. I suggest that this may be partially due to the lacking of professional trainings of GIS for archaeologists (Matsumoto 2005). Although there seem to have been a growing number of Anthropology departments that accept those techniques as one of the required research tools, they encourage their students to train themselves. Very few universities in the United States, Britain, and Australia provide comprehensive training in GIS and remote sensing techniques specifically designed for archaeologists. Notable exceptions include the University of Arkansas, the University of California at Santa Barbara, Boston University, Rutgers University, the University of York, University College at London, and the University of Sydney (Aldenderfer 2001). Thus, it has been a customary practice for archaeology students to take the courses concerning GIS and related technologies in Geography departments. Listed below are the offered courses during the academic year of 2007-2008 at SIUC that are relevant to archaeological studies.

Geographic Information Systems:
- GEOG 401: Introduction to GIS (Oyana, Wang; Fall 2007)
- GEOG 420: Advanced GIS Studies (Oyana; Spring 2008)
- GEOG 417: GIS Program Custom (Aduprah; Fall 2007)

Remote Sensing:
- GEOG 406: Introduction to Remote Sensing (Wang; Fall 2007)
- GEOG 408: Advanced Remote Sensing (Wang; Spring 2008)

Spatial Analysis:
- GEOG 404: Spatial Analysis (Oyana; Spinrg 2008)

Through these courses not only the principles and concepts of GIS and related techniques and operating instructions of popular software such as ArcGIS and ERDAS IMAGINE, but also a series of spatial analyses and programming will be covered. However, because those courses are originally designed for geography majors, the course materials and contents do not necessarily fit our needs.

Regarding the data, for instance, what they use in these courses is primarily ready-to-use data sets downloadable from the web (e.g., vector shapefiles, SRTM-arc3 DEM[2], and Census 2000 TIGER/Line Data[3]). In contrast, archaeological researches tend to occur in the regions that have not yet established an efficient (or reliable) geographical data management or related infrastructures and thus do not have enough data sources to

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[2] SRTM is a joint project of the National Imagery and Mapping Agency (NIMA) and NASA to map the world in three dimensions. During a single Space Shuttle mission on February 11 to 22, 2000, SRTM collected single-pass radar interferometry data covering 119.51 million square km of the earth's surface, including over 99.9 percent of the land area between 60°N and 56°S latitude. This represents approximately 80 percent of the total land surface worldwide and is home to nearly 95 percent of the world's population (Lillesand et al. 2004:712).

[3] The Census 2000 TIGER/Line Data consist of selected geographic and cartographic information extracted from the Topologically Integrated Geographic Encoding and Referencing (TIGER) database of the United States Census Bureau. See http://www.census.gov/geo/www/tiger/tiger2k/tgr2000.html for more information.

achieve the research aims. Archaeologists are almost always required to produce their own maps within budgetary restrictions. Furthermore, the procedures required for a site mapping actually go far beyond the scope of introductory courses of GIS and remote sensing. Softcopy photogrammetry techniques in particular are not involved even in the advanced courses listed above and thus need to be studied on your own. Consequently, an attempt to make use of the knowledge and skills obtained from those courses for his/her own archaeological research may be easily aborted at a very early stage.

More importantly, it goes without saying that the GIS courses in Geography departments are completely lacking of theoretical discussions about space and spatial phenomena in archaeology. Seibert (2006:XIX) cogently points out that "while GIS does represent an important methodological tool for archaeologists seeking to examine materials in a spatial context, it is important to note that GIS does not represent a theoretical approach in and of itself." In order for a research tool to secure a solid position as an archaeological method, however, it should be anchored by underlying theoretical debates and summoned by a set of archaeological problems. Thus, it follows that we need not only to acquire the knowledge and skills of GIS but also to keep track of the history of spatio-temporal thinking in archaeology and to discuss how GIS came to be integrated into the methodological and theoretical developments of archaeology. It is not until the wheels of theory and method turn around in a balanced manner that an archaeological research can go straight ahead.

Aimed at solving these problems, here I propose to establish a new course of GIS for archaeologists in our department of Anthropology.

A Prospective Syllabus

Then, what does a prospective syllabus for the proposed course look like? Basically, what we need to do is eliminate what is taught in the Geography department and add what is missing and necessary. Based on the discussions above, I suggest that the course should consist of the following four components: (1) discussions about spatio-temporal thinking in archaeology from the late 19th century to this millennium; (2) a guideline for data preparation and management; (3) an introduction to the major analytical methods of GIS applications in archaeology; and (4) laboratory exercises for the second and third. In addition, as Nathan Craig (Personal Communication, 2007) confessed that a good GIS reference for archaeologists may take the form of a collection of useful tips, to provide convenient know-how gained through field and laboratory works may also be an important component of this course.

What I would like to emphasize most is the importance of the first component: the history of spatio-temporal thinking in archaeology. We should deliberate at the beginning what have been problems throughout the history and what problems can be solved by means of GIS. In that the proposed course will be an extension of introductory GIS course to cover the methodological and theoretical developments of archaeology, it is not merely a technical training but should be aimed at achieving what we may call "spatial archaeology" after Clarke (1977).

Conclusion

It is obvious that there will be a steady demand among archaeologists for intensive GIS training over the next decade. Introducing a regular program of GIS from Geography and tailoring it to the specific needs of archaeologists and anthropologists in general is urgently needed.

Last but not least, regarding the inter-subdisciplinary nature of this seminar, it is important to emphasize the compatibility of the proposed course with other subfields of anthropology. In this paper, I have argued for the necessity to tailor GIS trainings exclusively for archaeologists. However, it would be quite possible to extend our scope to include the interests of other subfields of anthropology. Additionally, among the four subfields, archaeology would be most concerned with spatial and temporal aspects of sociocultural phenomena. This is the pivotal point at which we archaeologists may be able to contribute to the theoretical and methodological development of anthropology in general.

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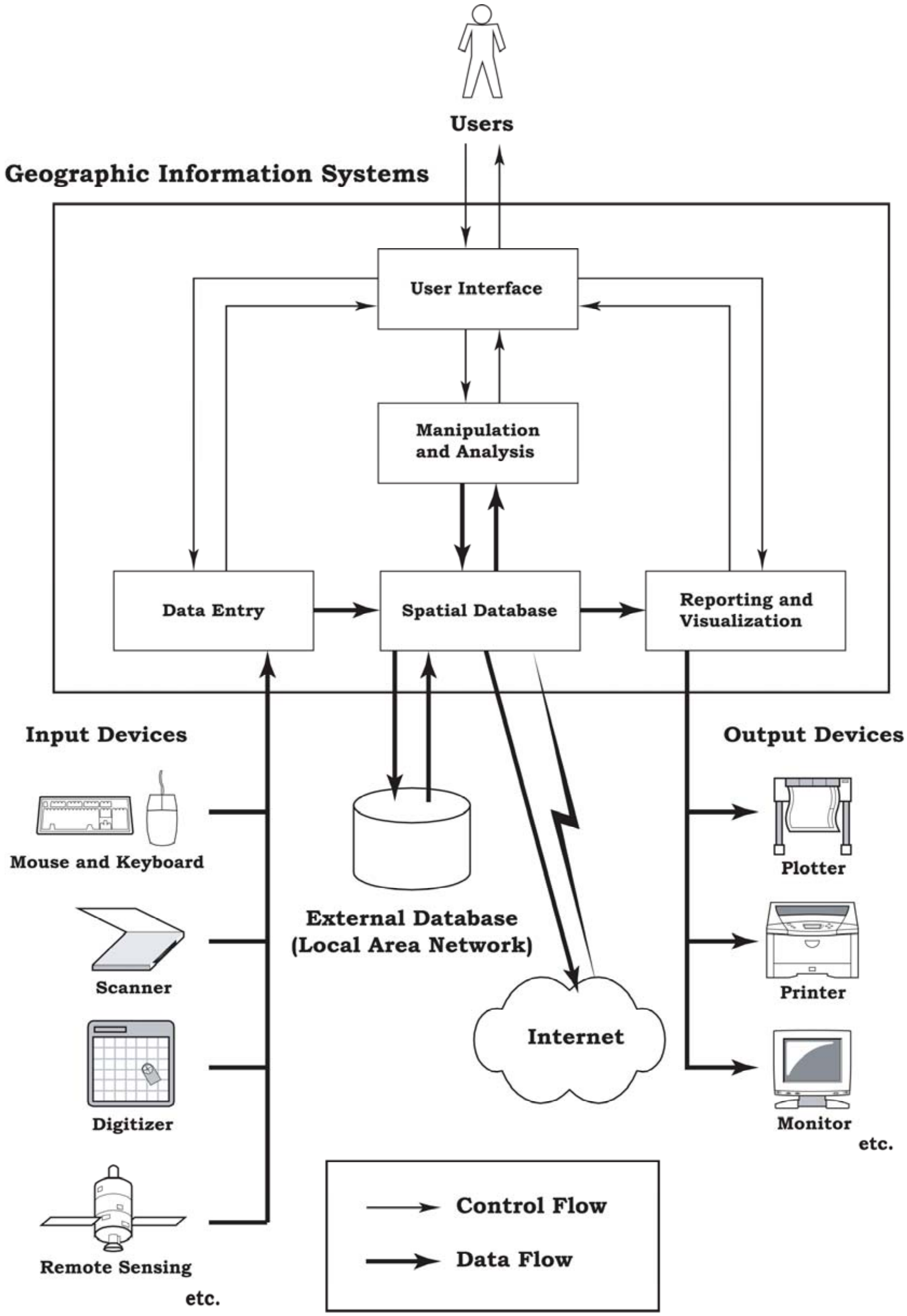

Figure 1: The logical subsystem model of GIS originally put forward by Marble (1990) (Taken from Wheatley and Gillings 2002: 11, Figure 1.2 and partially modified).

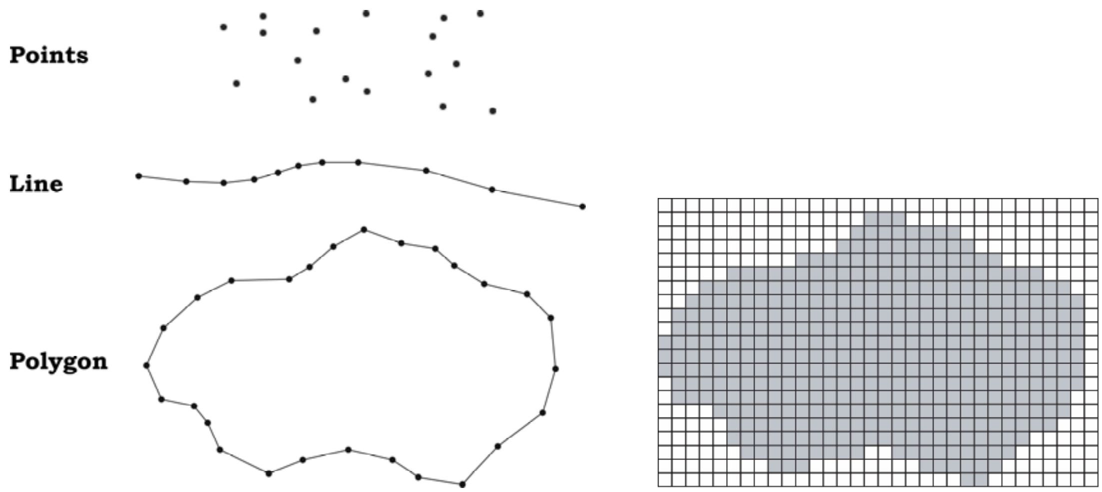

Figure 2: Vector (left) and raster (right) representations of geographic features.

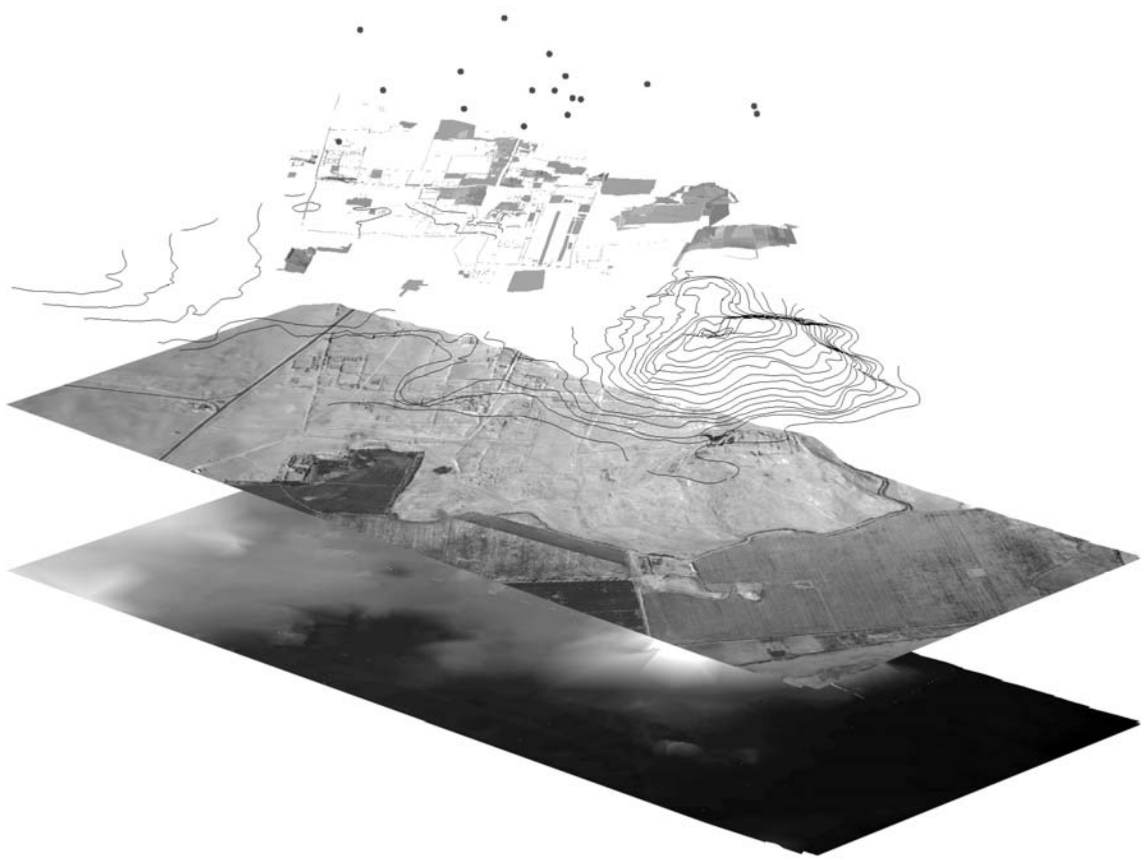

Figure 3: A GIS overlay consisting of GPS measurements, archaeological structures, contour lines, aerial photograph, and Digital Elevation Model (from top to bottom).