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E-learning Archaeology

the Heritage Handbook

Marjolijn Kok
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AAC-Themata 5DEF-v.a.12 verloop.indd 3 12-03-13 15:29

Table of Contents

05

Geographic Information System as a method of management of spatial data *by Christopher Sevara*

MSCO Introduction

Archaeologists devote a significant amount of time to the evaluation of space. The examination of spaces that others have occupied and of the things they filled those spaces with is what helps us to define our perceptions of people, households, sites, communities and cultures. In order to do so, archaeologists use maps, tabular information, images, and text to help communicate ideas about the value of space in the past. Geographic (sometimes referred to as Geographical) Information Systems (GIS) is the collective name for diverse computer software packages which can be used to bring together those and other elements into a framework in which they can be visualized, analyzed and shared (Conolly & Lake 2006:11, Wheatley & Gillings 2002:9). This acronym can be both singular and plural, so one could speak of working with 'a GIS' or that 'many types of GIS are suitable for the display of vector data', for example. Incidentally, the term GIS is not to be confused with Geographic Information Sciences (GIScience or GISC), which is a term for the study of the structure, theoretical models, and core principles upon which a Geographic Information System operates. This module aims to provide a brief discussion of GIS in the context of its use in the humanities, as well as providing a background and solid introduction to the applications and types of information for which a GIS is well suited. Suggestions for further reading on the topics covered herein can be found at the end of this section.

MSCO GIS applications – a brief history

> *Animation*

Development of the first true GIS application is widely credited to Dr. Roger Tomlinson, who was the key developer of a computerized land management system for the Canadian Department of Forestry and Rural Development in 1962-63. While far from the systems in use today at its inception, the CGIS program contained a number of key features which are today seen as core GIS functions. These included the ability to view and utilize map data inside the framework of a projection or coordinate system, to overlay multiple kinds of information, to measure, and to store attribute data about map elements in separate tables.

In 1964, the Laboratory for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design was founded by Howard Fisher, and subsequently developed many of the key spatial data handling functions which were to form the foundations for the commercial, government, and open source GIS programs that would emerge in the decades to come.

These began to be widely applied in the 1980s when the price and availability of computer hardware powerful enough to run GIS applications made it possible for private-sector companies to begin to use GIS as a decision making tool, particularly in the fields of forestry and natural resources management.

Further development of GIS and computer mapping applications in the military and private sectors in the United States, Australia, the United Kingdom occurred during the 1960s and 70s.

→ LU GIS Applications and history *by Christopher Sevara*

SCO History of GIS in archaeology, cultural heritage management, and historical research

> *Animation*

Archaeologists have been using GIS applications for various types of spatial analyses since the late 1970's, especially in the United States where the power of GIS as a tool for statistical and spatial analyses was seen by some archaeologists as a ready compliment to the spatial-scientific approaches characteristic of the New Archaeology. Indeed, it can be considered that archaeologists were among the 'early adopters' of this technology, which is not surprising considering that change in the utilization of space through time is both a central topic of interest in archaeology and a key component of a GIS.

However, it has only been in the last 10 to 15 years that desktop computers have become powerful enough and software has become inexpensive enough for many GIS applications to be run quickly and easily from the office desk or in the field, as opposed to having to book time on a university or corporate mainframe to run what would today be considered even the least complex of calculations.

Equally important to the rapid spread of GIS in archaeology over the last decade has been the exponential growth of data storage for desktop computers and servers, allowing for the storage of large datasets which would previously have taken up inordinate amounts of server space. The increasing availability of satellite imagery, topographic maps from various local, state, and national agencies, and readymade datasets containing information about roads, structures, and other modern landscape data have, together with increased storage and computing power, made it possible for even the smallest projects to readily utilize the myriad of powerful functions that many of today's GIS applications offer. Indeed, many software programs which offer functionality available only to well financed and well connected projects less than a decade ago are now available free of charge by open-source applications. GIS based field data collection methods allow for near real-time visualization and analysis of archaeological sites while excavation is going on. Project data can easily and inexpensively be published to the World Wide Web, to be shared with colleagues around the world, the interested public, and government agencies.

SCO Historical GIS/Historical Research

> *Animation*

The ability to import scanned maps of historical landscapes and to reference them to known real-world locations, to georeference them, is a key function of many GIS applications which is of much use to archaeologists and historians. The utilization of GIS to extract and compare historical data about land use and change through time from them has given rise to a subfield of GIS known as Historical GIS, or HGIS. Principal approaches to data use in HGIS include the use of georeferenced historical maps in the analysis of past land use, the reconstruction of past property boundaries for statistical analyses, the overlay of historical census data, comparisons between historical and modern travel corridors, and analysis of change in urban boundaries over time. Indeed, the treatment of time as an attribute in GIS from both historical and prehistoric perspectives has been a topic of much interest with regard to applications of GIS in the humanities, and will be explored further in later sections of this module.

SCO Cultural Heritage Management

Many archaeologists and historians in the Cultural Heritage Management (CHM) sector were quick to grasp the potential of GIS as tools for the management and distribution of large amounts of georeferenced, attributable spatial information about the location of archaeological sites and monuments which could be combined with other forms of map information, such as land use, topographic and development maps to provide a readily accessible inventory of archaeological sites and monuments in relationship to natural resources and building projects.

Indeed, the structure of many traditional systems of archaeological site and monument records are actually conceptually quite similar to the way in which a GIS operates. In many traditional sites and monuments archives, the locations of sites are plotted onto paper topographic maps and given a unique identification number, which is indexed to a card or form which contains text and other nonspatial data about an archaeological site.

This is very similar to the way in which spatial and attribute data are stored in a GIS, and it is not surprising that some of the most prominent uses of GIS in cultural heritage management take the form of local, state and national digital Site and Monuments Records (SMRS) which use online map and database systems to allow users to locate cultural resources using a number of different criteria. By the early 1990s, many agencies responsible for dealing with the management of SMRS were evaluating the benefits of GIS as a tool for cultural resource information management. Systems such as the state of Arizona's AZSITE and the Swedish National Heritage board's FMIS (elaborated upon in section V) began to emerge already in the mid to late 1990s.

Some public and private agencies dealing with cultural resource management in the United States and Europe have been particularly interested in the potential cost benefits of predictive modeling, the process of analyzing information about the location of known cultural resources, past land use, topography and other factors to predict the locations of archaeological sites in order that development plans such as the building of new travel corridors and housing developments can be modified to avoid locations with the potential for high mitigation cost with regard to cultural resources. This approach has had mixed success and its inability to take into account non-quantifiable factors concerning human development and land use is just one of many criticisms which have been brought up with regard to its use though it sill continues to be explored and developed in both research and applied archaeological contexts.

> SCO Exercise

SCO References
- Conolly, J. & M. Lake, 2006. *Geographical Information Systems in Archaeology*. Cambridge, England: Cambridge University Press
- Gregory, I., 2003. *A Place in History: A Guide to using gis in Historical Research*. Oxford: Oxbow
- Longly, P. et al, 2005. *Geographic Information Systems and Science*. West Sussex: Wiley & Sons
- Wheatly, D. & M. Gillings, 2002. *Spatial Technology And Archaeology: The Archaeological Applications of GIS*. London: Taylor & Francis

→ LU GIS Applications and History – Further reading *by Christopher Sevara*

SCO Further reading
- Ausserer, K.F., W.Börner, M. Goriany & L. Karlhuber-Vöckl, (eds.), 2004. Enter the Past. The E-way into the four Dimensions of Cultural Heritage. From proc. CAA 2003, Computer Applications and Quantitative Methods in Archaeology. BAR *International Series* 1227, Oxford: Archaeopress
- Bonfant, C., F. Chiabrando & A. Spano, 2007. *Studies and Knowledge Fusion in Archaeological Site Maps Managed in a 3D GIS*. From proc. XXI International CIPA Symposium, Athens, Greece 2007
- Calori, L., C. Camporesi, S. Pescarin, M. Forte & A. Guidazzoli, 2005. Openheritage: An Integrated Approach to Web 3D Publication of Virtual Landscapes. From proc. ISPRS Working Group V/4 Workshop 3D-ARCH 2005: *Virtual Reconstruction and Visualisation of Complex Architectures*. Mestre-Venice, Italy, 22-24 August 2005
- Chapman, H., 2006. *Landscape Archaeology and GIS*. Stroud: Tempus Publishing
- Clark, Jeffrey T. & Emily M. Hagemeister, (eds.), 2007. Digital Discovery. Exploring New Frontiers in Human Heritage. CAA 2006. From proc. *Computer Applications and Quantitative Methods in Archaeology conference*. Archaeolingua, Budapest
- Conolly, J. & M. Lake, 2006. *Geographical Information Systems in Archaeology*. Cambridge, England: Cambridge University Press
- Evans, T & P. Daily, (eds.), 2006. *Digital Archaeology: bridging method and theory*. Oxon: Routledge
- Frischer, B. & A. Dakouri-Hild, (eds), 2008. Beyond Illustration: 2d and 3D Digital Technologies as Tools for Discovery in Archaeology. BAR *International Series* 1805. Oxford: Archaeopress
- Forte, M. & Williams, P.R. (eds) 2003. *The Reconstruction of Archaeological Landscapes through Digital Technology*. Oxford: Basingstoke Press
- Kennedy, M. & S. Kopp, 2000. *Understanding Map Projections*. Redlands: ESRI Press
- Lock, G., 2003. *Using Computers in Archaeology: towards virtual pasts*. London: Routledge
- Longly, P. et al, 2005. *Geographic Information Systems and Science*. West Sussex: Wiley & Sons
- Mehrer, M. & K. Wescott, 2006. *GIS and Archaeological Site Location Modeling*. London: Taylor & Francis
- Monmonier, M., 1993. *Mapping it Out: Expository Cartography for the Social Sciences and Humanities*. Chicago: University of Chicago Press
- Monmonier, M., 1996. *How to Lie With Maps*. Chicago: University of Chicago Press
- Kennedy, M. & S. Kopp, 2000. *Understanding Map Projections*. ESRI
- Tufte, E., 1990. *Envisioning Information*. Cheshire, Connecticut: Graphics Press
- Wade, T. & S. Sommer, (eds.) 2001. *A to Z GIS: An illustrated dictionary of geographic information systems*. Redlands: ESRI Press

→ LU Core components of a GIS *by Christopher Sevara*

SCO Core components of GIS

The learning curve for GIS applications can be steep, but most GIS applications share a basic structure and approach to displaying data. Though some of the core functionality of a GIS application is derived from cartographic principles, a GIS should not be viewed solely as an advanced computer mapping program, but rather as a spatially aware database, where cartographic data such as roads, archaeological sites, and topography are linked to attribute data, textual information which provides a description of the key features which the spatial data represent, and stored in tabular format similar to tables made of rows and columns in a traditional database application. This means that a GIS has the ability to link information about where things are with information about what things are, something that traditional paper maps cannot easily do. While a computer application which is designed for cartographic output deals mainly with readying map data for static digital or paper output, a GIS application is able to store dynamic, updatable spatial and tabular information about geographic elements.

> Common elements of a desktop GIS application:
> click the points to open window and see description

> ***Animation***
> A map window, where geographic information is displayed. A layer manager, where different types of data can be sorted and activated for viewing and analysis. A toolbox and other tools for the viewing and manipulation of map data. Coordinates, 2 or 3 dimensional numerical values which describe a point on the surface of the earth relative to the location of another point, are also displayed.
> Map data and attribute data can be queried, requested from the GIS application through either a point-and-click function or a written function such as one used to request information from a database. This allows the user of a GIS to perform analyses on data, asking questions such as 'Where are archaeological sites from a particular time period located?', 'What is their spatial relationship to each other?', 'Can one site be seen from another?' and so forth.

However, the analyses performed and visualizations created from data in a GIS are only as good as the quality of the information, the data, which are contained within a GIS. Understanding what types of data can be utilized within a GIS and how they are constructed is necessary for evaluating whether a GIS application will be a useful component of a project workflow.

SCO Data and data types

Like other computer programs, the information utilized inside a GIS framework to perform the functions outlined above are referred to in generic terms as data. Data may be one of the most over- and misused terms within GIS in archaeology, not to mention the wider discipline. Indeed, the implications of the word 'data' have been the subject of much debate between and within different schools of thought within archaeology for a number of years. For the purposes of this module data is a word used to describe a collection of related information arranged in a particular format, and is thus generally used in plural form.

> ***Animation***

A GIS works with spatial data and their attributes. Spatial data fall into two main formats, raster and vector. Spatial data are represented within the context of a two or three dimensional coordinate system, a set of mathematical principles used to define points in space (presented in more detail below).

Attribute data associated with raster and vector data are stored in tabular format in a structure that users of traditional database management systems will be familiar with. Raster and vector data are abstractions of past or present real world events and places, such as the location of archaeological sites or three-dimensional models of past or present landscapes, which are represented as layers in a GIS.

Information in a GIS can therefore be used in the manner of a spatial database, whose complexity can vary according to the design of the data model, the rules and structures which govern how data are organized within an information system. Although different GIS applications have their own systems and formats for handling these two data types and some GIS applications are designed to work with primarily one data type over another, the basic properties of raster and vector data are largely platform independent. Many commercial software applications which deal with spatial data read or can import most popular proprietary data formats, as can many free and open source GIS programs.

SCO Raster Data

Raster datasets are continuous datasets which consist of picture elements (pixels) as their smallest unit of measure, or resolution. These are usually square in shape, but can have other forms. Raster datasets are generally referred to in terms of their resolution, expressed in terms of the geographic length and width of each pixel. When referring to raster datasets, pixels are often referred to as grid cells. The raster data structure consists of rows and columns of cells in which each cell stores a numeric attribute which is displayed as a particular color in a GIS, according to user definitions. The raster data format is often used in archaeology in the display and analysis of georeferenced aerial photographs, topographic maps, elevation models, and other elements which have a continuous surface.

> Tick examples of raster data in the table below.

> Exercise

Vector Data

Vector datasets are discreet datasets which are used to define points in space, linear elements, and boundaries of objects in 2 or 3 dimensions as geometric objects. The vector data model is generally comprised of three main components; mappable objects, related attribute data (discussed in greater detail in the next segment), and topological data.

> ***Animation***

There are three main forms of mappable objects, also known as geometric primitives:

> *Point* – a single point in space representing a location, as defined by a pair or triplet of coordinates.

> *Line* – a series of connected points with a known start and end. A line must consist of at least two points.

> *Polygon* – (also known as boundaries or areas) line or series of lines which enclose a space to form a boundary. Polygons must consist of at least three points.

Each of these three object types can be used to represent information in particular ways. If a user of a GIS wanted to display and analyze data about archaeological site locations within a region, those sites might be well represented by single points if the only geospatial component of interest about them were their locations. Roads and other linear features such as rivers might be represented by lines, while polygons might be used to represent features where area could be a significant concern. On a site level, the boundary of a site might be represented with a polygon, in order to be able to make calculations about the area the site covers. Features on the site might be represented using

both lines and polygons, while diagnostic artifacts, whose location in space may be more important than the volume of space they occupy, might be represented as points. These examples illustrate the fact that some care needs to be taken when deciding which types of geometric objects are best suited for the representation and analysis of information. More often than not, points, lines, and polygons are used in combination when collecting and representing information about archaeological sites and monuments in a vector environment.
Topological data in a vector system comprise rules about how vector objects share geometry, such as whether adjacent polygons share boundaries, or whether linear structures which cross each other share nodes (points). Topology also defines rules about data integrity, such as whether or not there can be gaps between adjoining polygons. Defining topological rules in a complex vector dataset can mean a significant saving of space and computing power in that adjacent objects can share geometry rather than having to duplicate it.

> Exercise

SCO Attribute Data

Attribute data consist of information relevant to particular spatial information and are stored in tabular format similar in structure to a table in a database. Attribute data and spatial data together are elements of a dataset. In the simplest of vector data structures, each point, line, or polygon in a vector layer will be linked to a corresponding row of information in the attribute table. Each layer will have its own attribute table, the contents of which can, particularly with regard to vector data, be user definable. Thus, a vector dataset which contains information about the locations of archaeological sites in a given region may have a corresponding table of attribute data in which could be noted information such as site names, site time periods, and preservation status. Vector datasets which consist of the spatial dimensions of archaeological features excavated on a particular site may contain information about their feature type, relationship to other features on the site, artifact types recovered from the feature, and excavation notes. In a traditional raster dataset, the structure is slightly different. Instead of spatial data being linked to attribute data in a separate table, spatial and non-spatial data are contained within the same file. This has tended to limit the amount of non-spatial information that is able to be contained in a raster dataset. A number of GIS applications which handle raster data have come up with methods of linking raster data to more detailed attribute tables. This type of raster layer is generally referred to as a data frame. Attribute data make it possible to create complex queries regarding information in a GIS, and can make it possible to link individual spatial elements of an archaeological site together in a relational format similar to that of a relational database. Spatial data can also be represented visually by their associated attributes, allowing for the generation of thematic maps based on attribute information.

> Exercise: choose only examples of attribute types. Answer with yes or no.

SCO Coordinate systems

To better understand how geographic data are represented in a GIS application, it is necessary to discuss the mathematical frameworks within which spatial data operate. This will be necessarily brief, but for a more comprehensive overview of coordinate systems and their applications within the humanities, Geographical Information Systems in Archaeology and Archaeological Surveying and Mapping provide concise and cogent discussions regarding the issue.

> *Animation*

Coordinates are the basic numerical expression of a two or three-dimensional point in space. Coordinate systems allow for the representation of geographic data in a scalable, measurable form by defining how points in space relate to each other, and fall into two main categories, geographic and projected coordinate systems. Geographic coordinate systems are systems which use latitude and longitude to describe points in space on the earth, and angles and distances to describe relations between points. This is a good method for locating things on the surface of the earth, but is generally not suitable for representing spatial information in two dimensions, as is done when printing a map or visualizing data in a GIS. Projected coordinate systems translate or reduce latitude and longitude to grid based numerical coordinates through the use of a map projection, a mathematical model for the display of the curved surface of the earth onto a flat surface. This produces unavoidable distortion of the information being displayed, and various projections have been devised over the years by individuals and government agencies as a means of minimizing that distortion in various ways on local, regional, national and international scales. For more detailed information about map projections and the ways in which they can be applied in the representation of spatial data, chapter two of How to Lie with Maps and the book Understanding Map Projections both provide insight into the complex nature of geographic and projected coordinate systems.

→ LU Data input and processing *by Christopher Sevara*

SCO Data input and processing

There are many different GIS software packages available today, both commercial (for pay) and open source ('free' to a greater or lesser extent).

> *Animation*

Some GIS applications, such as the Swedish National Heritage Board's Intrasis (*http://www.intrasis.com*) and ArcTron (*http://www.arctron.com*) from ArcTron GMbH are even purpose built for archaeological data collection and management. The Oxford Archaeology unit OA Digital has also released an edition of the popular open source gvSIG software package (*http://oadigital.net/home*), which contains a number of advanced tools for the storage, visualization, analysis, and output of spatial data, and runs on Macintosh, Linux, and Windows platforms. There is not space enough here to debate the merits of the numerous and ever growing available GIS software titles, nor should the preceding examples of GIS software be considered endorsements of the products described. Those interested in comparisons of that nature may want to refer to *http://en.wikipedia.org/wiki/List_of_gis_software* as a starting point for more extensive research on the topic.

Determining whether to buy a software package, to use one that has been developed and made available free of charge, or even to develop a bespoke application designed to deal with specific needs of a project or agency is largely related to the uses to which spatially connected data will be put. This determination should be made at an early stage of any project, as ideas for the use of GIS applications in a given project are being formulated and discussed. For example, if a project will be dealing with large amounts of satellite imagery or other continuous data such as elevational datasets it naturally makes more sense to utilize a program which is designed for the analysis of those data types.

Most GIS applications run well on current desktop computer hardware and operating system platforms, including versions of Linux, UNIX, Macintosh OS X and the Windows family of operating systems. Hardware availability, cost, and software compatibility with given hardware are all things to consider when planning the use and deployment of GIS applications. Many modern field data collection devices are also designed to be used with GIS applications, and onboard software in in-field data collectors can store attribute data about measurement objects which helps to automate the flow of data from the field to the desktop.

Learn more

- *http://en.wikipedia.org/wiki/List_of_gis_software*
- *http://www.intrasis.com*
- *http://www.arctron.com/*
- *http://oadigital.net/home*

SCO Data capture

Raster and vector data are often used jointly in GIS applications . For instance, the locations of archaeological sites, represented as points, lines, or polygons in a vector layer, might be displayed over a satellite image (a raster layer) of an area of the earth's surface in order to illustrate the proximity of certain sites and monuments to other natural or cultural features, such as cities or bodies of water. Raster imagery such as aerial photos which show evidence of prehistoric activity in crop fields may be used as base layers from which visible archaeological features are digitized into vector layers, thus creating attributable spatial information which can be utilized in conjunction with other data for different types of spatial and statistical analyses. In order to utilize these diverse types of data in a GIS, datasets must either be collected in the field with digital recording equipment such as GPS receivers, Laser Scanners or Total Stations, or created from existing paper maps and archives through digitizing and other forms of manual data input. These are referred to as primary and secondary geographic data capture methods, respectively.

SCO Primary data capture

Primary data capture is the process of collecting geographic data in the field specifically for the use in the GIS component of a project.

> *Animation*

Primary vector data capture can include the use of Total Stations, GPS receivers, or other measuring devices which store digital spatial information in raw or reduced formats, and the subsequent direct transfer and processing of those data in a GIS. In an archaeological context, primary vector data capture could consist of measuring the outlines of features and the locations of finds and directly transferring them into a project GIS for near immediate display and analyses. Primary raster data capture includes the use of airborne remotely sensed images such as aerial photographs or satellite data, or terrestrial remote sensing techniques such as the use of ground penetrating radar (GPR) or magnetometry surveys to prospect for locations of subsurface archaeological features.

SCO Secondary data capture

Secondary data capture is the process of creating datasets from existing information sources such as paper maps, photographs, and other non-digital documents.

> *Animation*

Secondary raster data capture methods include the conversion of paper documents to digital images through the process of scanning documents using flatbed and sheet scanners. Once documents, such as old archaeological site maps, topographic maps or printed aerial photographs are scanned, they can be referenced to known points in space through the process of georeferencing, whereby digital images are loaded into a GIS application and known geographic locations on the images, such as road intersections, property boundaries, and topographic features are selected and assigned real-world coordinates. Once paper maps are scanned and referenced to known points in space they become scaled to a real world coordinate system, thus allowing maps from different periods produced in different sizes and measurement systems to be compared accurately and with relative ease. Digitalization of maps also serves another function. Data become more easily shareable and worry about degradation of fragile maps form repeated exposure to less than ideal atmospheric conditions ceases to be an issue. Not only does this relieve the impact of exposure on the object in question, it allows for the sharing of information in easily accessible digital archives.

Secondary vector data capture methods include digitizing of paper maps and images, and manual data entry of coordinates. Digitizing of paper documents can take two forms, heads up digitizing and heads down (or tablet) digitizing. Heads up digitizing methodology consists of creating point, line, or polygon features by tracing over feature locations on scanned and georeferenced digital imagery in a GIS application. Tablet digitizing is the process of affixing paper maps and images to a digitizing tablet, a device attached to a computer which consists of an electronic tablet and a puck, a mouse-like object used to georeference and trace over paper maps and imagery in order to create vector layers.

SCO Data transfer and data management

> *Animation*

Data capture can account for a significant amount of time spent in a GIS related endeavor. If the purpose of a project is to convert old paper archives into georeferenced, searchable datasets then this cannot be avoided. Indeed, many archaeological projects which utilize GIS applications must produce their own datasets as archaeological information in question, such as the location of features, may not exist in any prior digital form. Alternatively, readymade datasets such as modern political boundaries, land use information, aerial photographs and satellite imagery can be purchased or acquired from various private, regional or national government entities that have already performed this task.

Many countries have made archaeological site and monument data available online, and these data can generally be downloaded and utilized in GIS applications according to the rules and regulations of the providing agency. This is known as data transfer. Many agencies have World Wide Web (web) portals, such as the University of Maryland's Global Land Cover Facility (*http://landcover.org/index.shtml*), which allow users to search their datasets for availability, and download or order data accordingly. There is much free information available, although many quality datasets, especially high resolution satellite imagery, can be expensive. Preformatted spatial data which are available from external sources should generally come with information about the quality and accuracy of the dataset in question. This information is known as metadata, and will aid users in determining whether or not externally acquired datasets are suitable to the needs of their projects.

GIS applications have a number of ways of handling spatial and attribute data. Approaches can be as simple as creating individual raster and vector layers for overlay and analysis, to more complicated methods of storing and distributing datasets to multiple users through the development and use of a spatial database. Development and utilization of a spatial database which resides on a central computer server can have a number of advantages in situations where multiple users will need to have simultaneous access to the same data. For instance, when a dataset in a spatial database is updated, the updates are instantly available to all users of the system. This helps to prevent data drift, in which the same dataset is copied and modified by different users resulting in the existence of a number of similar iterations of the original dataset. Another useful application of a centralized spatial database is in distributing information to remote users via a network such as the World Wide Web. Examples of this in archaeology include the Sites and Monuments Records (SMRS) which a number of government organizations in various countries make site locations and other site information available through the use of a centralized server and web portal. This means that as site and monument information is updated by the maintaining agency it is instantly available to users of the service.

Generating metadata should always be a priority in the development of any dataset. Metadata are standardized information about a dataset, including the creator, any potential error in the data, the purpose, and sources used in the creation of the dataset. Proper metadata generation not only helps users to understand the context in which a dataset was created and its potential application, it also helps to guide users in updating and refining it. Of particular note in this respect is the Arts and Humanities Data Service (AHDS). The AHDS is a national service based in the United Kingdom and seeks to help define standards for the responsible creation and use of digital content, and to provide an online repository for catalogues of data and other digital resources created by projects in the Arts and Humanities. The AHDS Guides to Good Practice series (*http://ahds.ac.uk/creating/guides/index.htm*) include a number of straightforward, basic publications which deal with the application of GIS in archaeology, and there are a number of resources and tools on the site which aim to help users with the generation of metadata and the documentation of datasets in order to preserve them for future use.

Learn more

- *http://landcover.org/index.shtml*
- *http://ahds.ac.uk/creating/guides/index.htm*

> SCO Exercise

→ LU Application *by Christopher Sevara*

SCO Application

Now that the types of information available for use in a GIS have been discussed, we can turn our attention to ways in which datasets can be utilized in archeology and archaeological resource management. In addition to the examples already discussed in previous sections, what follows is a brief overview of some of the basic applications of GIS in fieldwork, analysis, resource management, map creation and content distribution. There are numerous applications for GIS in addition to the ones outlined below, and numerous facets of the topics discussed below which will not be examined here. More in-depth coverage of these topics can be found in the reference literature.

> ***Animation***

Fieldwork
Developing an in-field GIS based approach to recording sites, monuments, features, finds and landscape data can increase the speed and efficiency of archaeological fieldwork.

Analysis
Data collected in the field, data from secondary sources, or a combination thereof can be used to perform various types of intra- and inter-site spatial and statistical analyses.

Map creation
The role of cartography in archaeology is well established. Maps have long been a key tool of communication in the discipline, used to present interpretations of present remains of activity in past landscapes.

Resource management
Many governmental agencies utilize a combination of database, web and GIS applications to make information about archaeological sites and monuments available online to authorized users, including archaeologists, infrastructure and building firms, and the general public.

SCO Fieldwork

Integrating the use of GIS into the survey of sites and monuments as well as archaeological testing and excavation is becoming increasingly common. Developing an in-field GIS based approach to recording sites, monuments, features, finds and landscape data can increase the speed and efficiency of archaeological fieldwork. Modern surveying equipment such as total stations and precision GPS receivers can be integrated into project workflow as primary data capture devices and used to capture spatial and attribute data in the field, reducing or eliminating the need for manual measurement and top-planning. Data collected in the field can be uploaded into GIS applications at the end of each field day and with the help of coded attributes can be automatically or semi-automatically processed to present near immediate views of spatially referenced site data. Locations and dimensions of features and finds can be evaluated as they are uncovered and mapped, assisting project members by providing continuously updated maps and spatial content. Attribute data about objects on site can be input into GIS based documentation systems throughout the in-field portion of a project, providing a rich dataset which is available for use immediately during post-field phases of a project and eliminating some of the work that has traditionally been done in post-excavation or post-survey contexts.

SCO Analysis

> *Animation*

Data collected in the field, data from secondary sources, or a combination thereof can be used to perform various types of intra- and inter-site spatial and statistical analyses. The relative use of a particular analytical function will depend chiefly on the manner in which the data have been collected and attributed, as well as other factors such as data resolution. Regional datasets which deal with the location of a number of archaeological sites from multiple time periods can be combined with three-dimensional terrain models of the present and past landscape, land use information and other factors to perform landscape analyses such as viewshed and intervisibility analysis, which are concerned with the position of sites and monuments in the landscape in relationship to their cultural and natural surroundings. Topographic models can be generated from points collected in the field or from remotely sensed data to form the basis of topographic maps or as a component for various surface modeling techniques such as site catchment analysis, the analysis of the location of archaeological sites in relationship to available resources or for cost surface analysis, the generation of potential past travel routes in the landscape based on the difficulty of traversing the terrain as well as other factors such as natural barriers, load, and environmental factors.

On an intra-site level, point location of finds encountered during survey or excavation can be used in artifact distribution analysis which can offer insight into the particular use of certain areas of an archaeological site, especially when used in connection with other spatial data such as the location of structures or room blocks. Attribute data about finds associated with cultural layers measured at an excavation can be used to produce maps of change through time with regard to artifact distribution on site. Sample locations and their results can be analyzed to illustrate temporal distribution of the contexts from which they came as well as locations of recovered organic materials. Structural elements mapped and input into a GIS application can be attributed with information about which time phase they may belong to, allowing users to query datasets for the display of site phase maps. These data can be combined with other local and regional information in order to try to understand the site location and activities in the context of the wider prehistoric landscape.

SCO Resource management

Many governmental agencies utilize a combination of database, web and GIS applications to make information about archaeological sites and monuments available online to authorized users, including archaeologists, infrastructure and building firms, and the general public. If an agency is already using GIS based applications for field data collection and analysis, the development and use of a centralized data content service to disseminate that information makes particular sense. Online Site and Monument Records (SMRS) incorporate elements of primary and secondary data capture in the form of updating of site and monument locations with data collected in the field as well as the digitalization of paper archives relating to sites already recorded. Records are generally presented for query as interactive, map-based web applications which allow the user to perform both spatial and attribute queries regarding cultural resources, to view query results, and in some cases to print or download requested datasets. English Heritage has numerous online resources dedicated to managing heritage data (*http://www.english-heritage.org.uk/server/show/nav.1545*). Systems such as the Swedish National Heritage Board's FMIS (*http://www.fmis.raa.se/cocoon/fornsok/search.html*) and the state of Arizona's AZSITE system in the USA (*http://azmap.asu.edu*) are just a few examples of the successful implementation of online GIS based archaeological and historical resource management applications . Both AZSITE and FMIS present the locations and attributes of sites and monuments to users, combining layers which contain data about cultural resources with topographic, economic, natural resource, and modern political boundary data and presenting these data in a map-based format, allowing users to select the information they are interested in through searches of both spatial and attribute data. Resulting datasets can then be printed out or requested in digital format for use in GIS applications.

SCO Map creation and content distribution

> *Animation*

The role of cartography in archaeology is well established. Maps have long been a key tool of communication in the discipline, used to present interpretations of present remains of activity in past landscapes. Most GIS applications deal in some way with cartographic output, indeed, this aspect of a GIS may be what many in the humanities are most familiar with. GIS applications are often utilized for map production and output in archaeology, especially in the Cultural Heritage Management sector, where factors such as rapid excavation in advance of construction and short turnaround times between fieldwork and report completion necessitate the rapid production of high quality, spatially accurate maps depicting impacted and potentially impacted resources.

> SCO Exercise

→ LU Issues and limitations *by Christopher Sevara*

SCO Issues and limitations

There are a number of things many current GIS packages do not deal well with. Of chief concern to archaeologists and heritage managers are how a GIS deals with volume and time. Most GIS applications display and process data whose coordinates can be 3-dimensional, but where lines and polygons are concerned the objects are '2.5-dimensional', representing only a face or section of a surface. This can lead to issues when using GIS applications to deal with volumetric calculations. Recently, the use of volumetric pixels, or voxels, for the recording and analysis of stratigraphic data at archaeological sites has been explored, with interesting and successful results.

Dealing with an active element such as time can also be difficult in many of the GIS software packages available today. This is largely due to the static way in which a layer-based GIS deals with information. The layer-based approach works fine if time is just a static component of an information set, for instance if a dataset has an attribute column which denotes the time period a site or monument is associated with. Where it becomes problematic is when trying to account for an object's change through time in a spatial sense, such as the movement or change in shape of an object over a given number of years.

> Exercise: answer with yes or no

→ LU GIS Put into practice *by Christopher Sevara*

SCO Further reading

- Ausserer, K.F., W. Börner, M. Goriany & L. Karlhuber-Vöckl, (eds.), 2004. Enter the Past. The E-way into the four Dimensions of Cultural Heritage. From proc. CAA 2003, Computer Applications and Quantitative Methods in Archaeology. BAR *International Series* 1227, Oxford: Archaeopress
- Bonfant, C., F. Chiabrando & A. Spano, 2007. *Studies and Knowledge Fusion in Archaeological Site Maps Managed in a 3D GIS*. From proc. XXI International CIPA Symposium, Athens, Greece 2007
- Calori, L., C. Camporesi, S. Pescarin, M. Forte & A. Guidazzoli, 2005. Openheritage: An Integrated Approach to Web 3D Publication of Virtual Landscapes. From proc. ISPRS Working Group V/4 Workshop 3D-ARCH 2005: *Virtual Reconstruction and Visualisation of Complex Architectures*. Mestre-Venice, Italy, 22-24 August 2005
- Chapman, H., 2006. *Landscape Archaeology and GIS*. Stroud: Tempus Publishing
- Clark, Jeffrey T. & Emily M. Hagemeister, (eds.), 2007. Digital Discovery. Exploring New Frontiers in Human Heritage. CAA 2006. From proc. *Computer Applications and Quantitative Methods in Archaeology conference*. Archaeolingua, Budapest
- Conolly, J. & M. Lake, 2006. *Geographical Information Systems in Archaeology*. Cambridge, England: Cambridge University Press
- Evans, T & P. Daily, (eds.), 2006. *Digital Archaeology: bridging method and theory*. Oxon: Routledge
- Frischer, B. & A. Dakouri-Hild, (eds.), 2008. Beyond Illustration: 2d and 3d Digital Technologies as Tools for Discovery in Archaeology. BAR *International Series* 1805. Oxford: Archaeopress
- Forte, M. & P.R. Williams, (eds.), 2003. *The Reconstruction of Archaeological Landscapes through Digital Technology*. Oxford: Basingstoke Press
- Howard, P., 2007. *Archaeological Surveying and Mapping: Recording and Depicting the Landscape*. London: Routledge
- Kennedy, M. & S. Kopp, 2000. *Understanding Map Projections*. Redlands: ESRI Press
- Lock, G., 2003. *Using Computers in Archaeology: towards virtual pasts*. London: Routledge
- Longly, P. et al, 2005. *Geographic Information Systems and Science*. West Sussex: Wiley & Sons
- Mehrer, M. & K. Wescott, 2006. *GIS and Archaeological Site Location Modeling*. London: Taylor & Francis
- Monmonier, M., 1993. *Mapping it Out: Expository Cartography for the Social Sciences and Humanities*. Chicago: University of Chicago Press
- Monmonier, M., 1996. *How to Lie With Maps*. Chicago: University of Chicago Press
- Kennedy, M. & S. Kopp, 2000. *Understanding Map Projections*. ESRI
- Tufte, E., 1990. *Envisioning Information*. Cheshire, Connecticut: Graphics Press
- Wade, T. & S. Sommer, (eds.), 2001. *A to Z GIS: An illustrated dictionary of geographic information systems*. Redlands: ESRI Press

→ LU GIS In archaeology – Terminology *by Christopher Sevara*

SCO Terminology

GIS applications have a heavily customized terminology, and publications relating to the subject sometimes have a tendency to lean toward the indiscriminate use of complex terms and abbreviations so similar in nature that even those with much experience in the subject can be left scratching their heads in confusion. This is further exacerbated by the fact that the topic is essentially a combination of cartographic, computing, and statistical principles all of which have their own heavily jargonized means of expression. It has been noted that discussions regarding GIS, irrespective of discipline, tend to be off putting for people with little prior exposure to the subject, and these highly specialized terms no doubt have much to do with that. Nevertheless, they are a necessary component of the discipline and should be both understood and used correctly. A brief description of some of the main terms used in this module can be found below. For a more complete reference of terminology, the book A to Z GIS: an illustrated dictionary of geographic information systems (Wade & Sommer 2001) is a useful starting point. Conolly & Lake (2006) contains a glossary of GIS terms with an archaeological perspective.

> *Attribute* – Information about spatial data, stored in tabular format.
> *Coordinate* – A set of values, usually numeric, which define a two or three-dimensional point in space.
> *Data Capture* – The process of acquiring information to be used in a GIS, either directly through fieldwork (primary data capture) or by processing non-digital information such as paper maps and site records (secondary data capture).
> *Data Drift* – A process in which multiple copies of the same dataset are edited by different users at different times, resulting in numerous versions of the same dataset.
> *Dataset* – A collection of related spatial and tabular information.
> *Data Transfer* – The process of acquiring a readymade dataset from a third party for use in a GIS application.
> *Digitize* – To convert analog (paper or like) spatial datasets such as maps into referenced digital datasets by tracing their features through the use of a digitizing tablet (heads-down digitizing) or by scanning and georeferencing the resulting image (heads-up digitizing).
> *Georeference* – To align or reference geographic data to a known coordinate system in order to be able to utilize it in relationship to other spatial data.
> *GIS* – Geographic(al) Information System, a collection of computer hardware and software which can be used to collect, organize, store, view, analyze and output spatial and associated attribute data.
> *Grid Cell* – See Pixel.
> *Layer* – A collection of similar geographic and attribute information.
> *Metadata* –Standardized information about a dataset, such as the name of the dataset creator, the date it was created, the quality of the data, or references to the data source.
> *Orthophotograph (Orthophoto)* – An orthorectified photograph in which distortions such as angle of the camera, lens distortion, and topographic relief have been removed, leaving the photograph with a similar scale throughout the image area. An orthophoto can be an aerial photograph, a photograph of a feature, or the like.
> *Orthorectification* – The process of removing the distortion in a photograph and referencing it to a known coordinate system, in which a series of ground control points whose coordinates are known are identified and referenced within the image.
> *Pixel* – Short for Picture Element, the smallest component of a raster dataset. Often referred to as a grid cell in GIS vernacular.
> *Predictive Modeling* – The mathematical process of combining a number of cultural and natural spatial and attribute data in order to predict probable locations of archaeological sites and monuments.
> *Projection* – A mathematical model which transforms the curved surface of the earth into a flat surface.
> *Raster* – A grid (pixel) based continuous dataset which stores information in equally sized cells ordered in rows and columns.
> *Remote Sensing* – The process of collecting information about an area from a distance. This can include collecting satellite imagery as well as ground based methods which seek the locations of subsurface features without excavation.

> *Stereo Photogrammetry* – The use of pairs of orthorectified photographs to produce three-dimensional images which can be used to extract topographic or other feature information.
> *Table* – Nonspatial attribute data arranged in rows and columns, often linked to spatial data.
> *Vector* – A discreet dataset which is used to define points in space, linear elements, and boundaries of objects in 2 or 3 dimensions as geometric objects.

MSCO References

- Conolly, J. & M. Lake, 2006. *Geographical Information Systems in Archaeology*. Cambridge, England: Cambridge University Press
- *http://www.archatlas.org/Home.php*
- *http://azmap.asu.edu/*
- *http://www.english-heritage.org.uk/server/show/nav.1545*
- *http://www.fmis.raa.se/cocoon/fornsok/search.html*
- *http://www.thebanmappingproject.com/*
- Howard, P., 2007. *Archaeological Surveying and Mapping: Recording and Depicting the Landscape*. London: Routledge
- Lock, G., 2003. *Using Computers in Archaeology: towards virtual pasts.* London: Routledge
- Monmonier, M., 1993. *Mapping it Out: Expository Cartography for the Social Sciences and Humanities*. Chicago: University of Chicago Press
- Wheatly, D. & M. Gillings, 002. *Spatial Technology And Archaeology: The Archaeological Applications of GIS*. London: Taylor & Francis