Archeologia e Calcolatori
8, 1997, 9-26

ARCHEOLOGY AND GIS: THE VIEW FROM OUTSIDE

1. Introduction

Geographical Information Systems (GIS) loom on the horizon of archeology like a change in the weather. And, like a change in the weather, the technology has prompted a great deal of discussion, variously provoking reactions of delight, trepidation and downright terror. As a geographer I have watched my own discipline move through a sequence of reactions to GIS in the past decade or so that started with general ignorance and that culminated (for the most part) in an acceptance of the technology as a valuable tool for contemporary scholars. At a recent meeting of the International Union of Prehistoric and Protohistoric Sciences (UISPP), in Forlì, Italy, it became apparent that, beyond a small cadre of specialists, the archeological community still has serious reservations and misconceptions about GIS. This paper is an attempt to address some of those concerns.

I shall resist the temptation to construct a complex narrative or lengthy commentary on the ironies and analogies that can be drawn from the problems of introducing new technology to this particular community. Likewise I shall avoid a discussion of GIS as a new paradigm in archeology – I share the reservations expressed by, amongst others, Thomas Kuhn (1970, 249 ff.), about the designation of any significant change in method or theory as a paradigmatic revolution.

Instead I shall argue that GIS represents a major development in method that can open the door to significant developments in methodology. To make this argument I shall first typify the current applications of GIS to archeological questions. I shall then suggest how the changes initiated by these applications may play themselves out in the future development of the discipline. I shall leave my discussion of the epistemological and ontological implications of these developments until the end of the paper. The central point of this last part of my argument is that GIS has forced a reconstruction of metaphors of both space and time on its users. This change of metaphors has its origins in the transformation of the relationship between the real world, the data used to describe the world, and the data terrain created in the process of making a GIS model using those data.

2. GIS

GIS is a blanket term used to describe a number of computer technologies that share the ability to record and manipulate data that have some spatial characteristics or components. In other words, any datum of which a significant characteristic is either its absolute or relative position in space can be stored and analyzed in a GIS. The diligence with which archeologists record and discuss the spatial characteristics of data both within and between sites and regions indicates that this concern with the spatial saturates the discipline. The importance of spatial analysis can still be seen, both in seminal works such as HODDER and ORTON'S (1976) book *Spatial Analysis in Archeology* and in the countless maps, site drawings, sketches and survey reports that make up the canon of contemporary archeological research.

Although there are several technological approaches to GIS available (including such things as triangulated irregular networks: TIN), for all practical purposes only two types of system are currently available to the working archeologist: raster and vector. I shall limit my discussion to these two types of GIS.

Vector systems represent space by creating graphical objects, which are then labeled and linked to a relational database. Two building blocks are used to construct these graphical objects: points and lines. The points represent discrete locations within a Cartesian coordinate system, and can also be used to define the beginning and ending of lines and line segments. Lines can represent connections between points, and can be used to enclose areas. This means that all data in a vector system must be described by one of three basic graphical elements: points, lines and areas. Vector systems can be seen as analogue devices in that they graphically represent space in a similar way to traditional cartography. As such they have an atavistic appeal to those familiar with pen-and-ink methods of recording spatial data. Apart from this appeal they are also particularly useful for their ability to link complex multi-field data bases to graphical images that represent landscapes in an immediately recognizable way. Although not as elegant as raster GIS for many types of modeling, vector systems are singularly good at simulating the behavior of networks.

Raster systems are those in which space is mapped as a patchwork of grid cells, each endowed with a characteristic. Although these characteristics are ultimately all digital, they can be visually represented in a number of ways: as colors, greyscales, or as values in some other non-spatial data representation, such as a histogram. The elegance and utility of raster GIS lies in its capacity to generate a gestalt. The combination of a complete matrix of cells creates what might be termed a data terrain, that can both represent existing landscapes, and simulate dynamic behavior through time. In the first instance coding cells by color allows for the creation of composite images in much the same way as a mosaic or a pointillist painting is created. In the second instance mathematical manipulation of values in data cells allows for their structured transformation. If the mathematical models employed are sufficiently sophisticated the researcher is able to simulate processes associated with some quite complex landscape changes.

3. Current Applications in Archeology

There are three areas in which archeologists have employed GIS: map-making and data visualization; data base management; and analysis. I shall deal with each in turn. Before proceeding I should note that I make no claim to originality in this section. There are several excellent sources for comprehensive reviews of GIS in archeology. Foremost among these are Kvamme's (1989) essay *Geographic information systems in regional archeological research and data management* and Allen, Green and Zubrow's (1990) collection of essays *Interpreting Space: GIS and Archeology.* I have drawn upon these two sources extensively in writing this part of my essay.

3.1 *Map-making and data visualization*

As noted above vector GIS in particular resembles other methods of representing spatial data graphically. However, a common misconception seems to be that it is a viable map-making tool. This is simply not true. There are several desktop mapping software packages which allow for the production of excellent graphical output (e.g. Mapinfo), and several full-blown vector GIS packages which have user-friendly graphical production modules (e.g. ArcView).

Creating a vector GIS data structure in order to produce a map is a very complicated way of accomplishing something that can be done much more easily in other ways. Using a vector GIS to draw a map is rather like using a shotgun to open a can of ham: no matter how long you stalk the can, how well you hide yourself, or how accurate your shot you're still not a hunter – and it would have been much easier to use a can opener. For simple map-making tasks pen and paper, PC drawing packages and computer aided drafting (CAD) packages remain by far the best technologies.

For other kinds of data visualization, such as making screen displays, both vector and raster GIS can serve a useful purpose. The ability to create rapidly and display graphically the distribution, location and spatial organization of data can be extremely useful. As can the capacity that many packages now have for producing other, non-spatial representations of data, such as histograms, pie charts, and simple descriptive statistics. However, such output should not be confused with analysis. There is a veritable minefield of confusion and misunderstanding surrounding the graphical representation and analysis of spatial data objects. A lengthy discussion of these issues is beyond the scope of this paper but I have devoted a brief section of my theoretical discussion below to some of the more obvious problems, and I have suggested some more detailed works on the subject.

3.2 *Data base management*

Managing, maintaining and navigating large and complex data structures is a perennial problem for archeologists. This is true both for research archeologists and those concerned with cultural resource management and rescue archeology. It is in this realm that vector GIS comes into its own. Desktop vector systems (i.e. those that can be run on a standard personal computer) are available that are capable of linking large and complex, multi-layer graphics to data bases with several hundred fields. In other words, it is possible to create a data structure in which each element of an area that is represented graphically can be described in a multitude of ways, from location, perimeter and area, through age, date of excavation, and artifactual content, to such arcanae as the name of the archeologists who excavated it (e.g. BAMPTON, HAMILTON 1996).

As the data are stored in a relational data base it is possible to search, sort and reclassify them quite easily; most desktop systems use standard query language (SQL). Anyone who is familiar with Boolean operators like "if", "and", "or" , "unless" and so on can quite easily extract useful data or combinations of data from complex data sets. Further, data sets can be enhanced by adding data fields to the database (or by removing them!). This combination of capabilities greatly facilitates navigation and maintenance of large databases. When considering the sheer size of some of the data sets currently being gathered, the utility of this application becomes apparent. Simon Holdaway, currently working in New South Whales, has a field area that is somewhat larger than Belgium. Recording the thousands of artifacts surface gathered in this soil-less badland environment is a simply monumental task only made possible by the use of a GIS database, compiled using among other things two total stations, and several palm-top computers (HOLDAWAY 1996).

The elegance of vector GIS in this application is its ability to create multi-dimensional data structures, and to articulate complex hierarchies of data. Any datum can be positioned on a multitude of axes within a single conceptual space – a real-world geographical coordinate system. Thus a feature can have a Cartesian x and y coordinate location, a location on a z axis to indicate its temporal or stratigraphic location. It can then be positioned on a series of axes that match subsequent data fields. Within this space the distribution, relational position and clustering of features can be explored by careful sorting and specification of fields.

To add further sophistication to an already complex system, as all data are positioned within a single coordinate system, images rendered at different scales, from the individual site to the regional can be "nested" within each other. In other words, it is not necessary to render all images at a common scale, to tie them into the same data structure.

Many of the data management capabilities outlined are all familiar to archeologists: all have been employed before. What is new is the size and complexity of the data sets that can be managed in this way, the speed with which they can be manipulated and updated, and the facility with which they can be shared with others, and combined with data from external sources. Simply for the sake of this data management function, GIS offers a host of interesting possibilities to working archeologists. And although cultural resource management is seen in some circles as the black sheep of archeological research, the bulk of excavation, and the vast majority of the archeological data currently retrieved, are collected under its aegis. This being the case, a technology that offers accurate, accessible and versatile recording of information is to be welcomed.

3.3 *Modeling*

GIS offers a barely explored potential as a modeling tool for archeologists. There are essentially two research tasks that can usefully be accomplished in this way. Existing data can be manipulated and processed to reveal relationships, and interactions, and simulations can be created.

The manipulation and processing of existing data is an outgrowth of the database management functions of GIS, and centers on pattern recognition in data sets – that is the identification of spatial distributions, coincidences and correlations. And as in the case of data base management it is the ability of computers to handle large and complex data sets with speed and precision that makes GIS useful in this capacity. Put rather more prosaically it might be said that GIS offers the possibility for researchers to ask "what if? " questions rather more readily than was previously possible.

A second and rather specialized case of this type of re-examination of existing data in search of some meaningful or interesting "signal" is the exploration of remotely sensed images using raster GIS. The capacity of the raster systems that incorporate some image processing capabilities to "pull" information about ground surface characteristics from images enables researchers to identify otherwise undiscernible features. One of the more creative examples of this type of application has been in the area of nondestructive subsurface survey. This technique has been successfully used to identify and map such things as building foundations using data gathered from magnetic resonance signals. While not quite at the advanced stage of the "Tricorder" used by Science Officer Spock of the Starship-Enterprise, this technique does hold considerable promise for preliminary survey.

Perhaps the most adventurous application of GIS to archeological analysis is in the creation of speculative simulation models. By combining some knowledge (or hypothesis) of processual relationships with a digital model of landscape it is possible to model the effects of that relationship in space and time, and to do so reiteratively. This allows the researcher to explore the effects of different parameters upon the same relationship. For example by establishing a relationship between climate, elevation and vegetation type it is possible to make some quite good models of past vegetation distributions on a landscape under different climatic conditions. If there is a strong correlation between site location and vegetation then it is a relatively straightforward business to produce a series of past habitation distributions for varying climatic conditions.

The recent history of archeology is littered with questionable predictive models – however I do not see this as a particularly good reason to abandon the undertaking, merely a good reason to approach it equipped with appropriate scientific caution. Virtually any other process in which a mappable spatial phenomenon is correlated with a process, and which has a mappable outcome or consequence can be modeled in this way. For example such things as resource catchment areas, and distribution of agriculture can be explored using this type of technique.

Much of the work undertaken in this area to date centers on the use of raster systems to create simulations of landscapes – though a couple of scholars have employed the rather novel strategy of creating vector data sets that have a cell structure that emulates a raster system (e.g. JOHNSON 1996).

An ambitious attempt to use raster modeling, and to do so in a way that is informed by the discussions of post-processual archeology, can be found in the work of KOHLER and GUMERMAN (1996). These authors report on a project in which rule-bound agents are released into an "artificial world" (sic), and the long-term impacts of their interaction with the environment then simulated. Despite a superficial relationship to the normative models of the sixties and seventies, many of which were roundly criticized for their failure to consider such things as human decision-making capacity, KOHLER and GUMERMAN (1996, 104) have managed to, in their own words:

> «. . . honor the individuality and variability of actors and the fact that their interactions are inherently local».

An area which, to the best of my knowledge, remains to be explored is the network modeling capability of the more sophisticated vector systems. Vector networks are ideal for modeling flow patterns and communication links. Networks maps allow for the modeling of flows along pathways with both directional and frictional impedances, with stops, barriers, turns and junctions. In other words, they are like subway systems. The subway lines are the connections between points, and the trains moving along them are (hopefully) constrained by rules of speed and direction. The stations, or points, serve as boarding and embarking points; in some cases they are also the end of the line, in some cases they also allow for transfer between lines, in some cases they are simply barriers to further movement. The capacity of this type of system for modeling complex communication patterns, resource flows and interactions across space remain to be discovered by research archeologists.

Needless to say, all of the analyses generated in this way are exactly as sophisticated and accurate as the thinking of the researcher, and their quality is directly proportional to the quality of the data and analytical models used. Indeed an overarching caveat for GIS use in archeology, or any other field for that matter, is that it is no substitute for rigorous and logical thinking. Each of the examples I have outlined above will doubtless provoke withering criticism in some circles. In anticipation of such criticism I offer the thought that the deficiencies of my examples are not an inherent reason to dismiss GIS as an analytical tool. Working on the assumption that there are discernable patterns and relationships in the archeological record that can give some insight onto the history of past human cultures, I merely suggest GIS as one efficient (and rather entertaining) way of unearthing some of these relationships.

4. Theoretical problems of GIS identified by archeologists

One of the issues to emerge in the Forlì Colloquium was a considerable trepidation amongst many eminent archeologists as to the harm that might be done to archeological research by widespread adoption of GIS. Two main problems were identified. GIS was seen forcing further separation between the already divided communities of academic archeology and contract and cultural resource management archeology. And a danger was seen in the ability of the technology to produce impressive output and seductive graphics which might conceal spurious reasoning and bad data, essentially the substituting of GIS for scientific rigor and theoretical understanding. I shall briefly review each of these arguments in turn, and in the following section add a third and final area of concern: the problems confronted by those who fail to understand the nature of spatial data.

In contrasting research archeologists who ask interesting questions with administrative (CRM) archeologists who do not, Torsten Madsen (1996) laments that the former lack the will, skill and resources to explore GIS applications. From the rather bleak picture he presents it would appear that, at least in Scandinavia, GIS is destined to serve as a wedge driving research and rescue archeology apart. This presents archeology with something of an existential crisis – if there really are two separate communities, and they really don't serve each other, why bother to save archeological resources? The *raison d être* of CRM is to preserve the archeological record for the sake of science and the collective cultural edification realized by structured research. In Madsen's words (1996, 132):

> «There is a growing gap between a more and more mechanical rescue archeology on the one hand, heavily financed and open to new technology but totally devoid of research ambitions; and an academic archeology on the other hand accepting new technology, but modestly financed and increasingly con-

> cerned with "reading the past" rather than with the data they supposedly read. The paradox of the situation is that archeologists not interested in research becomes well acquainted with a methodology that has a very high research potential; while archeologists, who could do with the methodology that has a very high research potential, hardly know what it is. . .».

The possibility of visual seduction offered by GIS, and the danger of substituting scientific form for theoretical content has preoccupied several commentators. The problem they identify is what Richard FEYNAMAN (1985) has called "cargo cult science". He suggests that there is a type of science that resembles the cargo cults which were widespread in some regions of the Pacific during the early and middle part of the twentieth century. The adherents, observing that people talking into radios were able to summon flying machines full of good things, reached the entirely reasonable conclusion that this was a religious ceremony – put on the magic hat, talk into the magic box, and the stuff will show up. So they put on headphones, and talked into model wireless sets, and built model airplanes, and waited for their share of the goods to arrive. There is a distinct possibility that GIS may become the current magic hat of archeology: it requires considerable material and intellectual resources to operationalize a GIS; impressive arrays of data, correlations and cartographic representations can rapidly be produced; and, a great many blinking lights, cryptic screen messages and bleeps accompany the work of any self-respecting GIS.

Frederick LIMP (1996) and Albertus VOORRIPS (1996) provide useful overviews of how this problem manifests itself. LIMP (1996, 116) warns of a descent into the vulgar materialism of environmental determinism:

> «. . . it is clear that methodologies which make it easy to manipulate environmental data may unwittingly lead to such data taking inappropriate precedence in the understanding of human societies».

VOORRIPS (1996, 211-212) warns of the precedence of aesthetics over understanding:

> «. . . for approaches to the study of archeology which are not holistic and which [do] not try to explain the archeological record in terms of searching for patterning in space and/or time, GIS has nothing to offer bu the production of pretty-looking, meaningless pictures».

Added to these informed criticisms, articulated by the initiates of GIS, there seems to be a lurking techno-phobia amongst archeologists that can be heard whispered in the corridors of conferences and that follows any unfortunate who is identified as a technician of some kind.

5. THE PROBLEMS OF CARTOGRAPHIC REPRESENTATION AND SPATIAL DATA

There is third area of potential problems, as yet unexplored in the archeological literature: the failure of those working with spatial data to appreciate its characteristics. It has become a commonplace among geographers and cartographers to acknowledge the problems of cartographic representation and spatial data. These difficulties center on the translation of the complex and continuously varying surfaces of the world into the discrete graphical elements of a map. Regardless of the type of map – whether it is paper or electronic – cartography is a simplification of the real world.

The visual characteristics of any map exert a huge, and often unacknowledged, influence on the interpretations that its audience make. Authors such as the cartographers Mark MONMONIER (1991) and Brian HARLEY (1994) have devoted considerable energy to exploring both the technological and ideological consequences of this aspect of cartography.

Monmonier focuses his attention on the mechanics of representation, discussing such things as scale, symbolization, color, use of text, line quality and composition as influences on interpretation. He notes the advantage of cartographic representation is also its problem: as maps simplify and order the world, effectively functioning as models of reality, so they filter our perceptions eliminating, enhancing or concealing information. A poorly designed map can thus lead to serious misunderstandings about the nature of the landscape depicted. If designed with some mischief in mind maps can function as powerful and malign propaganda tools.

Harley's argument focuses on the broader social function of maps. Drawing on the ideas of literary critical theorists he notes that mapmakers are driven by a host of considerations that fall far beyond the realm of surveying and representing the world as accurately as possible. Mapmaking conventions, decisions about what to represent, how to represent it and how to characterize the world are all highly charged with ideological, psychological and political meaning. The decisions made by the cartographer about what to name things, for example, has huge and lasting historical consequences – as any Bosnian will attest.

Taking both of these discussions into consideration, it becomes apparent that map making and map reading are highly complex tasks that demand respectively the coding and decoding of an intricate web of meaning. There is a distressing tendency among non-specialists to regard maps as simple, objective documentation, similar to illustrations and photographs. The most striking similarity, of course, is that illustrative drawing and photography are also both exercises in interpretation, and should be approached with similar caution. A map, drawing, or photograph is not a simple reflection of the real world, rather it is a multi-layered text in which explicit, implicit, concealed and unconscious interpretations are combined. If there is a single rule for negotiating this hazardous terrain, either as author or audience, it is that images should be approached with the same informed scepticism as any other text.

The primary problem of spatial data is that the conceptual devices for representing any phenomenon are rather limited. For all practical purposes the researcher is limited to one of four options: the point, the line, the area, or the cell. Given these choices mapping a landscape, such as that presented by an excavation or a cultural region, poses a number of problems.

There are few features, apart from individual measurements such as elevations, that are really Euclidean points. Yet many things are conveniently represented as points: trees, hearths, settlements, to name but a few. All of these things have some area. Representing them with position, but no magnitude is not necessarily a problem, but it does require the sacrifice of at least one important dimension.

A similar problem exists with lines. There are only a few things that can be accurately represented as a line of no width. For the most part linear features such as roads and rivers do have an area.

Areas and cells present some similar problems: both show homogeneity within their boundaries. That is, both assume that all significant change occurs at boundaries. There are some phenomena such as political units which are truly homogenous: one is in the state of Maine, until one is half-way over the Kitterey Bridge, then one is in New Hampshire. However the vast majority of things represented as areas or cells are heterogenous in some way, and are not separated by absolute boundaries. Thus a cell representing deciduous forest is not uniformly and exclusively filled with deciduous trees, and a bounded area representing a mudflat does not accurately represent the edges of the mudflat. In reality, both forests and mudflats tend to be rather ill-defined and changeable.

All of these difficulties of spatial data representation originate from the process of gathering discrete data to describe phenomena that are complex and continuous. Apart from some simple inaccuracies that result from representing things as that which they are not (such as recording trees as points and roads as lines) there is a set of more complex analytical problems which arise.

I shall not attempt to provide an exhaustive list of these difficulties here; there are several specialized texts which explore such ideas in greater depth (e.g. MARTIN 1991). However the general problems can be illustrated with reference to one frequently encountered difficulty that should be familiar to anyone conversant with the fundamental principles of statistical analysis.

This is the modifiable areal unit problem (MAUP) (OPENSHAW 1984), a special case of the ecological fallacy that affects spatial data. The ecological fallacy is that aggregated data do not necessarily have the characteristics of the populations from which they were derived. Thus, for instance, a mean may not share the attributes of any single individual in the population from which it was calculated. The MAUP arises when populations are defined using spatial criteria. An aggregate value (however derived) describing a population falling within a boundary will not necessarily accurately reflect the characteristics any individual. Redrawing the boundary differently on the same terrain will yield a different aggregate value.

This is not merely a theoretical curiosity; it can present some quite immediate problems. It means that, in effect, aggregate values for population data are as much an artifact of boundary definition as they are a reflection of population characteristics. Further, by remapping boundaries of a given terrain an entirely new set of attributes can be suggested for a location assigned to a new polygon, despite an unchanged reality.

The problems outlined above are all inherent characteristics of spatial data. They are not restricted to GIS users – as a glance at the cartographic materials presented in any daily newspaper will reveal – but the widespread adoption of GIS as a spatial analytical tool by researchers who are not aware of the theories of spatial analysis will certainly spawn a host of projects that embody the difficulties described. I suspect that the next decade will bring a string of real howlers in GIS, on a par with the most spectacular pratfalls of statistical analysis identified in the seventies and eighties.

6. Theory

At this point it seems wise to pay some attention to the theoretical and philosophical consequences of these developments. And no matter how impassioned the pleas from the archeological community that the application of the new technology be driven by theoretical considerations, and that it take into account the hard-won understandings of past workers, it remains inevitable that the technology will to some extent drive theoretical developments.

Separating out the methodological and epistemological changes from the ontological is rather difficult as each, of necessity, impact the others. However I have tried to outline below some of the more obvious trajectories that I anticipate will grow from the spread of GIS in archeology, first in the realm of praxis and secondly in the metaphysical realm of ontology. Central to my argument in this section is the notion that using GIS, by forcing a reconceptualization of data and the way they describe the world we seek to study, forces us to adopt new metaphors of space and time.

6.1 *Praxis*

The data handling capabilities of GIS mean that there is a great increase in the number of data types now accessible to archeologists; large volumes of data can now practically be included in models; integrating a multitude of spatial scales within a single model is now possible. In the realm of modeling the change centers on the ability of GIS to create dynamic landscape models that can be reiteratively tested.

The types of data available to archeologists working with GIS is increasing exponentially. Georeferenced data of any kind can now, at least in principle, be added to models. When one considers for a moment the sheer volume of material currently available in digital form or currently being rendered into that form the potential impact of this development becomes apparent. Remotely sensed images, raw data and analytical coverages produced by a variety of institutions, agencies and individuals can be included within the matrix of variables to be considered when studying any particular place or region.

Obviously there are a host of practical issues surrounding the question of access to such data, a host of reliability issues surrounding data accuracy, and a host of technical issues surrounding the question of importing and formatting data of different origins. Yet it remains that these unconventional and unexpected data are becoming increasingly available, and offer the possibility of introducing a variety of new variables to archeological analyses.

The ability of GIS to process and manipulate large numbers of data is discussed in the preceding section. This is not merely a convenience; it also offers a (partial) solution to an old archeological conundrum. The data handling capabilities of GIS offer some insulation against what might be termed the "Schliemann syndrome" – the destruction of potentially useful data in the course of a single-minded search. Of course there is still no way of knowing which of the things that end up in the back-fill will be of interest to future researchers: in this respect all excavations suffer from the Schliemann syndrome.

Still the ability to record and cross-reference large volumes of data in a form that is readily accessible allows for a rather more liberal attitude to speculative data collection: if it looks as if it might be interesting one day, you can make some record of it. The development of data recording technologies such as digital photography, and the ability to link these records to a broader GIS data base will only enhance this capability.

The integration of spatial scales allows for the connection of individual observations, excavations, landscape contexts and entire regions in a single conceptual framework. Linking observations to a common georeferencing system does two important things: it quite literally connects otherwise widely separated locations into a single map; and, it links the phenomena depicted on that map into a single coherent reality, continuous in both space and time.

The connection between spatio-temporal scales of study and phenomena identified is widely recognized in geography (for two very different explorations of this argument see SCHUMM, LICHTEY 1965, and HAGGETT 1990). I suspect that the methodologies of both the day-to-day practice of data retrieval and processing, and broader long-term research objectives will be influenced by this development. In both cases the possibility that observations can be included in regional, and ultimately global data models will quite literally change the perspective of researchers. Although the definition of site and region boundaries, and temporal periodization, have always been recognized as a contentious issues, the truly arbitrary nature of such boundaries and divisions becomes unavoidable when data are linked into a single frame of reference, as they must be in a GIS.

6.2 *Metaphor*

The development of qualitatively new modeling techniques, as discussed in the preceding section, will allow for a kind of speculation not previously possible. Until now the empirical testing of archeological theories rested on further excavation and experimental archeology. With the development of GIS modeling capabilities model landscapes can be operationalized. Although rather limited at present, there are ever-increasing potentials for building complex multi-variate simulations of past human societies, and the environments they inhabit.

Reconstructing one's spatio-temporal reference framework has consequences that reach far beyond methodology and epistemology. The changes described above will have some significant ontological consequences. I suggest that the driving force in this case is a transformation of the metaphors of space and time that arises as a consequence of using GIS. These transformations manifest themselves in four realms: in representations of space itself; in the reference system within which objects are positioned; in the temporal indicators encoded in the output; and, in the relationship between an image's author and its reader.

In what follows I will repeatedly contrast GIS with something that I shall call "traditional cartography". My anthropological colleagues constantly warn me against the dangers of using the word "traditional" loosely; likewise the cartographic historians would correct any attempt I might make to suggest that there is a single cartographic canon, venerable and pure, to which anyone subscribes. However, for convenience I shall use the term to refer to the production of paper maps that use the combination of symbolic representations, colors and text to depict survey data. A more exact and eloquent definition of maps is provided by BLAUT (1971, 19):

> «Maps fall into the general semantic category of semi-pictorial or semi-iconic sign-systems, those in which the up-down and left-right dimensions correspond to those of a real or imaginary visual field. Within this class they belong to a vaguely defined sub-category of image systems involving conventionally, a downward view of the earth's surface with the top of one's real or imaginary head pointed north. Most maps lie about midway in level of abstraction between highly realistic systems (for instance, aerial photographs) and highly schematic or abstract ones (for instance, location diagrams). But one essential feature of all such structural sign-systems, and for our purposes their most important fea-

ture, is the depiction of finite slices of process, either as narrowly dated as the moment during which the shutter of an aerial camera is open or as broadly dated the clock-time lapse between the earliest and latest events shown on a map».

In the first instance the conceptual framework within which space is modeled by GIS resembles that used in the cartography described by Blaut. A continuous and heterogenous surface is rendered into a set of discrete data entities – essentially a data model. Put another way, a pattern of lines, dots and shading is used to represent the complexities of real landscapes.

Beyond this, however, the two technologies have some important dissimilarities. In traditional cartography the link from real-world observation to measurement to data model to cartographic output is linear and uni-directional, and the output is essentially a static object. Reprocessing of the data demands the creation of a new data model and the production of a new map.

GIS reconstructs this process in a fundamental way. The relationship between the real world, measurement, data model, and output is mediated by an additional and complex set of models that exist within the machine (Martin 1991). In the first instance all data are rendered into a digital form, quite literally a mass of linked but discrete entities which create the impression of being coherent objects. Second, the objects and relationships coded into the machine are extremely dynamic: each image is created afresh from the data model each time it is viewed. Third, both the data model and the data themselves can be readily transformed. This, then, is essentially a non-linear relationship, and one in which the output is infinitely mutable. The metaphor of the map as a snapshot must be replaced by one of the map as an organic entity, capable of some quite dramatic changes from one viewing to the next.

The second transformation is in the reference system within which geographical objects are located. A necessity of GIS, discussed at greater length in the preceding section, is the creation of a georeferencing system. This is essentially the coordinate framework within which objects are located, and it is global and absolute. Traditional cartography allows for relative, or abstract positioning of objects. A conventional map can be drawn in an abstract conceptual space, in which orientation, global position, relative distance and a host of other positional data are reinterpreted, changed, or simply ignored.

By contrast GIS data, once transformed to a real-world coordinate system, exist within an absolute conceptual space. Or to look at it another way, *all* georeferenced GIS data, regardless of scale, subject, or even accuracy, are essentially part of the same data structure, we just haven't joined all the pieces together yet. Leaving aside the rather disturbing Orwellian implications of this observation, it is worth noting that this brings into question such spatially restrictive concepts as regional definitions. After all, in global terms there's only the one region.

An appropriate metaphor for a paper map is of a framed image. Both projection and georeferencing system are constrained by the borders of the paper, and cannot neccessarily be extended beyond them; consequently the geometric space within which the image exists is limited, and not all images are commensurate. However, the geometric space of the infinitely mutable coordinate system of a GIS creates an image which exists within a larger, continuous fabric of geographical data, in which a global geometric space is assumed, even if it is empty. Rather, then, than filling the space within a border with data, as a traditional maps does, a GIS image presents a window on a larger data surface, one that can be re-sized and repositioned at the behest of the user.

The third transformation is temporal. Traditional cartography codes time into output in two ways. First, in terms of what is represented: there is a linear link between real-world observation and final output, therefore what is drawn stands in an absolute temporal relationship to what is observed. Second, in the physical object produced, the map itself: the paper artifact, often bearing a date of survey and printing, is manufactured and ages as time passes.

By contrast in GIS there is no absolute temporal sequence between observation and output production. The physical object and the information it contains, be it screen image or paper map, can be produced and transformed at will. In other words, GIS does not freeze a single instant of time in the way a paper map does. Rather GIS images exist in a mobile and reciprocal relationship with the user, changing both in response to specific commands, and in those cases where some model has been coded into the system, in response to the internal dynamics of the data themselves. The metaphor of the map as an archival document, tied to a single point in time becomes one of the map as a newsflash.

The fourth transformation is in the realm of narrative. Traditional maps are presented to the reader as a *fait accompli* – placing them in a fixed relationship to the author. In this sense the reader is only active in the reinterpretation of the data coded into the map.

By contrast GIS data are re-authored by each reader who summons an image – a fact all to easily ignored even when screen prompts demand that the user specify locations to view, scale to view them at, colors, palettes, coverages, and so forth. Further, the system itself is an actor in that it also transforms, reorders and re-authors the data before presenting them. Thus a static text is no longer an appropriate metaphor for spatial data constructs, rather they are interactive or even proactive entities.

The net result of these four changes is the re-organization of our conceptual relationship to spatial data – I use the plural pronoun here simply because I believe these transformations are of importance beyond archeology. All of us working with spatial data are forced to reexamine the relationship between what we measure, and how we render that into some coded form; forced to reconstruct our notions of space as continuous *within* data models, as well as beyond them in the real world; forced to acknowledge the dynamic nature of the environment, rather than to imagine that we can make snapshots; and, forced to reposition ourselves in the complex transaction that connects author and reader of any text.

7. Conclusion

Two visions of GIS and archeology were juxtaposed in Forlì. In one established research archeologists expressed grave doubts as to the value of a technology that threatens classical theoretical traditions. In the second those with access to the technology extolled the virtues of this revolutionary new device. The second vision, which I find most exciting, does not necessarily exclude or devalue the first, sadly the evidence of Forlì is that those following the first vision have little time for the second.

Certainly, many of the problems identified in critques of GIS applications to archeological research are sustainable. And as I have suggested above, there are several problematic issues which have yet to be addressed in the archeological literature. Questions of technique and conceptualization remain unresloved. This said there is a whole world of new analytical possibilities awaiting those prepared to take risks, and to be a little reckless. A cautionary criticism of resistance to potentially iconoclastic methodologies such as GIS is provided by the anarchist philosopher, Paul Feyerabend (1975, 182) who remarks:

> «I am not surprised when experts who are advanced in years, who have a reputation to uphold (or to get quickly, before they die), and who quite naturally confound knowledge with mental rigor mortis look askance at attempts to loosen up science or to demonstrate that *great* science . . . is an intellectual adventure that knows of no limits, and recognizes no rules, not even the rules of logic. But I do find it a little astonishing to see with what fervor students and other non-initiates cling to stale phrases and decrepit principles as if a situation in which they bear the responsibility for *every* action and are the original cause of *every* regularity of the mind were quite unbearable to them».

This quotation provides a segue to the central point of the book from which it is taken: Feyerabend argues convincingly that in science *anything goes*.

GIS offers archeology the possibility for ingenious, inspired and playful theorizing at the cost of the trouble it takes to learn how to operate the software. Despite lamentations to the contrary, the technology has now reached a point where a standard desktop PC, even a dated, humble and affordable 386, can run powerful analytical software, and manipulate large and complex data sets. Digital data are not always readily available, yet the diligent and ingenious can create their own or contrive them from publicly available materials – this second option is one that will only become easier with the passing of time. If you take the time to learn how to run a full-scale GIS you will find yourself in a historical moment of opportunity: you can pull new correlations, new theories, and new understandings from your data, simply by being in a position to look at them in new ways. Posterity will certainly judge much of what is produced to be spurious or flawed, but so what? You'll have a lot of fun in the meantime, and you may actually discover something useful.

Matthew Bampton
Department of Geography-Anthropology
University of Southern Maine

BIBLIOGRAPHY

Allen K.M.S., Green S.W., Zubrow E.B.W. (eds.) 1990, *Interpreting Space: GIS and Archaeology*, London, New York, Philadelphia, Taylor & Francis.

Bampton M., Hamilton N.D. 1996, *GIS, education and stewardship in Casco Bay Estuary, Maine, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems*, Forlì, U.I.S.P.P., 59-66.

Blaut J. 1971, *Space, structure and maps*, «Tijdschrift voor Economische en Sociale Geograpfie», January-February, 18-21.

Eastman R. 1995, *Idrisi for Windows: User's Guide Version 1.0*, Worcester, Clark Labs for Cartographic Technology and Geographic Analysis, Clark University.

Feyerabend P. 1975, *Against Method*, London, Verso.

Feynaman R.P. 1985, *"Surely You're Joking Mr Feynaman! ": Adventures of a Curious Character*, New York, Norton.

Haggett P. 1990, *The Geographer's Art*, Oxford, Blackwell.

Harley J.B. 1994, *New England Cartography and the Native Americans*, in E.W. Baker, E.A. Churchill, R.S. D'Abate, K.L. Jones, V.A. Konrad, H.A. Prins (eds.), *American Beginnings: Exploration, Culture and Cartography in the Land of Norumbega*, Lincoln, University of Nebraska Press.

Hodder I., Orton C. 1976, *Spatial Analysis in Archaeology*, Cambridge, Cambridge University Press.

Holdaway S. 1996, *GIS and open site archeology in New South Whales, Australia, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems*, Forlì, U.I.S.P.P., 218 ss.

Johnson I. 1996, *Desktop mapping and raster GIS: best of both worlds?, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems*, Forlì, U.I.S.P.P., 89-52.

Kohler T.A., Gumerman G.J. 1996, *Beyond GIS: populating worlds with agents, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems*, Forlì, U.I.S.P.P., 101-111.

Kuhn T. 1970, *Reflections on my critics*, in I. Lakatos, A. Musgrave (eds.), *Criticism and the Growth of Knowledge*, Cambridge, Cambridge University Press.

Kvamme K.L. 1989, *Geographic information systems in regional archaeological research and data management*, in M.B. Schiffer (ed.), *Method and Theory in Archaeology*, Tucson, University of Arizona Press.

KVAMME K.L. 1996, *Randomization methods for statistical inference in raster GIS context, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems*, Forlì, U.I.S.P.P., 107-125.

LIMP W.F. 1996, *Developing methodologies in the analysis of spatially referenced data and their impacts on archaeological method and theory, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems,* Forlì, U.I.S.P.P., 115-125.

MADSEN T. 1996, *GIS and Scandinavian archaeology. A tale from the real world, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems*, Forlì, U.I.S.P.P., 127-135.

MARTIN D. 1991, *Geographic Information Systems and their Socio-Economic Applications*, London, Routledge.

MONMONIER M. 1991, *How to Lie with Maps*, Chicago, University of Chicago Press.

OPENSHAW S. 1984, *The Modifiable Areal Unit Problem*, Concepts and Techniques in Modern Geography 38, Norwich, Geo Books.

SCHUMM S.A., LICHTEY R.W. 1965, *Space, time and causality in geomorphology*, «American Journal of Science», 263, 110-119.

VOORRIPS A. 1996, *Archaeological theory and GIS, any relations?, Proceedings XIII International Congress of Prehistoric and Protohistoric Sciences, Forlì*, vol. 1, *Theoretical and Methodological Problems*, Forlì, U.I.S.P.P., 209-214.

ABSTRACT

The rapid spread of Geographical Information Systems (GIS) technology confronts archeologists with a number of opportunities and several dilemmas. Presentations and discussions at the 1996 U.I.S.P.P meeting in Forlì, Italy, suggested that the current contributions of GIS to archeological zeitgeist mixes new analytical possibilities, new data management capacities and theoretical problems. The current debate surrounding these issues is useful, yet it ignores several important areas of discussion. Many of the peculiarities of spatial data and spatial analysis have so far been overlooked, as have the changing metaphors of time and space demanded by GIS. A host of entertaining possibilities await those prepared to explore some of the remoter horizons opened by GIS.