Introduction
Geographical information systems have undergone a very
great expansion in archaeology during recent years (Allen et al.
1990; Lock/Stančič 1995). Important and recent advances in
the capabilities of GIS software have opened up new
possibilities for data analysis and display. For example,
developments in visualisation techniques (McLaren/Kennie
1989; Visvalingham 1994) have provided new approaches
in a variety of application areas including archaeology.

The expansion has three, amongst other, important
caracteristics and concomitant questions. Firstly, readily
available GIS software packages, requiring relatively cheap
hardware (e.g., PCs), have both facilitated and constrained
archaeological use. The packages have been developed for
non-archaeological use where, for instance, time is often of
a different order of magnitude. Are the current GIS
packages entirely suitable for archaeology given their
original aims? Secondly, certain assumptions of scale are
made in building environmental and archaeological
databases for analysis by GIS. For example, the extent to
which DEMs provide an adequate realisation of the terrain
of a site depends on the availability and characteristics of
the original source material (i.e. maps or aerial photographs).
How should archaeologists assess the relevant scale for the
implementation of a particular project? Thirdly, GIS
software has considerably aided the rapid assessment of
theoretical questions of a broadly environmental and
technological type which were prominent in the 1960s.
The data sources are physically and environmentally
deterministic and many approaches are technologically
deterministic in the way in which certain GIS packages
force the use of particular routines/algorithms. In the
meantime, archaeological theory has begun to stress other,
ideological, dimensions. Can GIS techniques address these
more ideological questions?

This paper addresses these three issues in the light of two
projects undertaken at the University of Bristol. The first
was a project in the Department of Computing Science
undertaken to develop a set of bespoke software tools for
the exploratory analysis of archaeological and environmen-
tal data from the Valley of Gubbio whose first stage has
already been published (Malone/Stoddart 1994) and whose
analysis is now entering the secondary stage. The second
was the work involved in preparing data for a TLTP
( Teaching and Learning Technology Programme) project to
aid the teaching of GIS, drawing on data from the Nepi area
of southeast Etruria, 40 km north of Rome. This is in turn
part of a longer term project covering the re-analysis of
settlement from a larger area of southeast Etruria, drawing
from material collected by the British School at Rome and
the Soprintendenza Archeologica per l’Etruria Meridionale.

2 Strategies towards increased flexibility: The
Gubbio example

The data for the survey of the Gubbio valley have been
published in the form of distribution maps of discrete sites,
alongside excavation results, environmental analysis and
overall interpretation of the Gubbio valley in comparison
with other areas of central Italy (Malone/Stoddart 1994).
As outlined in the introduction to the publication, this does
not do justice to the information available either from the
archaeological or environmental survey. The trial project
proposed within computer science was to set up a flexible
and interactive system to explore the relationship between
pedology and densities of archaeological artefacts (as
opposed to discrete sites). As currently implemented the
application is relatively simple and allows the overlaying of
different types of maps and the graphical representation of
frequency of site finds against landscape characteristics.

The aim was to develop a prototype system which would
provide a test bed for investigating extensions to the GIS
capabilities available in commercial systems. In most cases
these existing systems have not been developed with the
needs of the archaeological user in mind. For this reason,
there is a requirement to specify and implement a set of
customised tools for data analysis and display to support
archaeological investigations. An important feature of our
approach is the opportunity it provides for an archaeologist,
computer scientist and geographer to work together in an
interdisciplinary framework to develop new techniques for
geographical analysis of archaeological data. An important
element of this approach is the use of a prototype system to
demonstrate these techniques and facilitate communication
between potential users and system developers.
2.1 Specification for the Gubbio exercise

A trial area of the archaeological survey was selected for preliminary examination. Environmental data were supplied for the purposes of this exercise in two forms: contour maps and pedological maps. Archaeological data were supplied in the form of quantities of recovered material from point coordinates which represent an area. The full detail allowed by the field survey collection strategy can be incorporated at a later stage.

These different arrays of information were to be overlayed on top of each other, allowing comparison of archaeological and environmental data. The environmental data can be divided (although not entirely independent) into topographical (height, aspect and gradient) and pedological (soil type, drainage etc.). The maps were to be rescaled and histograms were to be calculated which show these relationships. Figure 1 shows a histogram of finds at different contour levels.

2.2 Implementation

The prototype system is PC based, operating under Windows and developed in C++. The user interface is shown in figure 2. An important aspect of the system is the design of this user interface which enables an intuitive easy-to-use point-and-click interface for most of the system functions. Despite recent advances in GIS software, many commercial systems still make extensive use of command languages in which the user has to enter keywords and parameters via the keyboard. The approach developed here makes full use of an object-orientated language within a Windows environment in an attempt to maximise use in an intuitive and fully interactive manner. The use of a graphical user interface (GUI) and visual programming elements allows the user to interact more naturally with complex spatial data such as landscape models.
The limited amount of resources available for the development of this system to date means that we have focused on illustrating a series of possibilities, to stimulate further discussion of the possible uses of GIS in archaeological analysis, rather than concentrating on the development of a polished software system. The system currently scales and rotates maps and plots artefact locations following parameters determined by the operator, as illustrated in figure 3. This is an ongoing project where it is our intention to explore varied presentations of DEMs, with interactive control of interpolation, aspect, gradient and visibility, and to introduce specific types of statistical analysis.

3 Strategies towards appropriate scale and ideological analysis: The Nepi example

The grand scale of the study of the South Etruria area is to visualise a changing political landscape over time principally from the middle of the second millennium through a series of major changes: Etruscan and Faliscan state formation, conquest by the Roman Empire, the decline of late Antiquity and the resurgence of the Middle Ages. The specific case study derives from an early stage in this process adopted for teaching purposes in the tutorial of GIS for a nationally funded UK computer aided teaching programme.

The Nepi dataset is characterised by two important facets: a fragmented terrain and a rich, but unsystematic, settlement dataset. The Nepi landscape is volcanic and dissected. The accuracy of the terrain model is therefore crucial. Horizontal distance is no measure of the physical effort in crossing terrain. The volcanic plateaux are apparently flat, but slight differences in height can also have a major effect on intervisibility. The dataset is rich, although in need of considerable data verification. One aspect of the richness is the presence of tomb as well as settlement data. These data have been usually collected by different strategies to the settlement data, but once integrated may allow a new dimension of analysis. It is well known that pre-Roman tombs were placed in visible positions outside towns, but geographical analysis might allow a more detailed analysis of this phenomenon.

Figure 3. Contour interpolation dialogue box.

Figure 4. Location of tombs in zones of visibility and inaccessibility.
3.1 PROBLEMS OF SCALE
In work on the Nepi dataset, considerable effort was devoted to the elaboration of height data at an appropriate scale. This becomes very important when visibility in this terrain is highly sensitive to small changes in height. The problem in assessing the scale for the analysis became particularly prominent given the difficulty of securing suitable maps which could answer the questions posed by a rich, but methodologically complex dataset. Satellite data are expensive and not necessarily sensitive to the needs of micro-analysis of site location. The most detailed digital data are available at 1:25,000 but still not necessarily sufficiently sensitive and also costly. One approach is to build up coverage from locally available maps at scales of 1:2000 - 1:4000 with concomitant problems of edge matching and error checking. Problems also had to be addressed in replacing cartographic symbols of significant drops in height over short horizontal distances (ravine edges) by digital data. A more satisfactory solution is to constitute the DEM from aerial photographic data, using photogrammetric software and this is currently being investigated.

3.2 IDEOLOGY
The rich dataset of tomb and settlement data can be played against each other. Figure 4 shows the concurrence of inaccessibility and visibility from the town at certain points in the landscape. These zones correlate very strongly with the presence of tombs which have a liminal quality in the ideology of the pre-Roman period. More detailed analysis on a broader landscape will allow the precise quantification of this relationship, drawing in minor settlements and roads into the equation.

4 Conclusion
These examples illustrate the need to increase interactivity, sensitivity to scale and broadening of the scope of GIS to less strictly environmental questions. New steps can only be provided by increasing the communication between specialists in different fields of activity and ensuring their mutual understanding.

Acknowledgements
Vanessa Blake is the author of the Toolbook application of the Nepi data.
references

Allen, K.  
S. Green  
E. Zubrow (eds)  

Lock, G.R.  
Z. Stančič (eds)  

Malone, C.A.T.  
S.K.F. Stoddart (eds)  

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