

# An Archaeological Geographical Information System in Arc/Info

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## Introduction

A Geographical Information System is a computer system for "capturing, storing, checking, manipulating, analyzing, and displaying data which are spatially referenced to the Earth" (DoE, 1987; Maguire, Goodchild, and Rhind, 1991).

This paper describes a methodology for using the GIS Arc/Info system as an operating tool to study and to archive excavation findings and structures, in an archaeological site.

The present study was developed, within a Project Work, for a Master's Degree in "Tecnologie avanzate dell'informazione e della comunicazione", at the E. Caianello International Institute for Advanced Scientific Studies (I.I.A.S.S.), Vietri, s.m. (SA- Italy).

The choice of the archaeological sample site, and the definition of information and methodologies, useful to the study and the management of the chosen site (Villa Rufolo, Ravello - Italy, fig.1 and fig. 2), were the result of the interaction, between a photogrammetry partnership (S.F.M.) and the N. Cilento, archaeological laboratory at Salerno University.

## ArcheoGis: an archaeological GIS

The GIS project involves two fundamental steps: design and implementation.

The design step is the one, in which GIS specialists and experts, of the field under observation (archaeologists), discuss and identify research goals.

In the implementation step, GIS specialists manipulate and analyze data, handed down from archaeologists, using the software logic in use, to obtain the research goals.

The ArcheoGis design was developed, starting from the analysis of methods, common to both research methodologies, landscape recognition and stratigraphic excavation, which characterize the phases of archaeological, data manipulation. The main idea was to create a tool which, starting from the planimetric documentation of each excavation, could link the various environments to their related stratigraphic units, through data, derived both, from each structure and from the artefacts.

## Recording data and development of the database

A digital map database consists of two types of information: spatial and descriptive. These are stored as a series of files, and contain both spatial and descriptive information about the features. The capacity of a GIS lies in linking these two types of data, and maintaining the spatial relationships, among the map features.

Database design involves three major steps: identification of geographic features, attributes, and data layers required; definition of the storage parameters for each attribute; and, inspection of co-ordinate registration.

Digital map implementation and the definition of an information model in the archaeological GIS, in Arc/Info system, were developed based on all those features, which may be used in the study of an archaeological site: stratigraphic schedules, excavation planimetries, excavation sections, sketches and photos of findings, and the Harris matrix.

The research team, of the N. Cilento Archaeological Laboratory, daily makes use of hardware and software tools, in recording data on-site, so much of the data was already in digital format.

Stratigraphic schedules were actually stored in Excel format, and planimetries, sections, and artifacts sketches were managed with CAD software, and stored in DWG format.

For the import of data into ARC/INFO environment, I started from a DBF format and a DXF format.

Only the Harris matrix, relating to the study site, was not in digital format, but for the purpose of this project, this was not necessary.

A map of a particular spatial feature (e. g., types of ground used for particular purposes) can be thought of as a layer of data, with regard to a specific area. In Arc/Info, these layers are called, "coverages".

The strategy I adopted, in organizing information about an archaeological site, allows many interpretations. One of the possibilities is to analyze each stratigraphic unit, according to its graphic and logic features, in order to achieve an integrated display of its various levels, which could provide information, regarding planimetric data. Such data were expected to have flexibility, and to show relationships and links, among phenomena.

Following this criteria I thought to create one coverage, for each stratigraphic unit. In the coverage, the stratigraphic unit would be stored like a feature polygon.

On the other side, I needed to achieve statistic information, to classify the whole of the stratigraphic units, that formed the settlement object of study; and, since Arc/Info tools are oriented to process one coverage at a time, I create one coverage, which stored all the stratigraphic units like feature points. As all the topological and spatial information, concerning the stratigraphic units would be preserved, because the points were the centroids of each polygon (which represented the stratigraphic units in each polygon coverage), it was possible to achieve statistic information, classifying the whole of the stratigraphic units, that formed the settlement object of study.

Finally, I created coverages for each archaeological finding, and for the sections of the excavation maps. These coverages only had a graphic function, and were not geographically referenced, so they were made up of arc features.

To make data import into Arc/Info easier and quicker, the stratigraphic units were stored in separate layers, in a CAD environment. Each layer named, with the name of the stratigraphic unit, which it held. Stratigraphic units of the same type were digitized, in the same color (fig. 3).

Type	Code color
Canal	140
Cistern	184
Shake	250
Window	14
Mouth of	204
Surrounding	181
Postholes	30
Pilaster	180
Door	24
Gathering water	194
Fill	20
Rock	9
Stairs	170
Ground	10
Wall	160
Tower	174
Trench	252
Reservoir	151

Fig. 3

The command sequences DXFINFO and DXFARC, of the ARC processor, allowed, respectively, the reading of various dxf layers, and their import into the suitable coverages.

To create spatial relationships, among the features in a coverage, it was necessary to build a topology; so, after importing, the next operations was entity correction (detecting missing arcs, missing labels, gaps between two arcs or unclosed polygons, etc.), and the building of topological relationships, among entities (each feature was assigned an internal number; these numbers were then used, to determine arc connectivity and polygon contiguity).

#### Performance analysis

At this point, I continued building the database for the project, before beginning the analysis and the creation of the final maps. Before the analysis could be done, I needed to specify additional data.

In ArcheoGis, I stored information, connected to graphic data, and I grouped this data into three classes:

1. information about geometric and geographical references of graphic elements,
2. information, derived from schedules, that is collected from stratigraphic schedules, recorded during archaeological excavations, and
3. information on which analysis procedures have been organized.

According to Arc/Info data models I arranged all information into a relational database. The stratigraphic unit (US) attribute was the link connecting the graphic elements, the geographical and spatial database, and the descriptive database (fig. 4). In such a way, when I selected a graphic element, I automatically obtained geometric data (area, perimeter, etc.), descriptive data (store code for each stratigraphic unit, number of findings in the selected stratigraphic unit, types of findings, etc.), and the results of analytical processes (statistics and classifications).

Adding additional attributes, about features into a coverage, involves associating new information, about each feature, to already existing records. Records, in the two tables, can be associated through a common item (US). A common procedure is to merge the two tables, using a relational join. A relational join matches a record in one table, to a corresponding record, in another table, when the value for the common item is the same.

Having geo-referenced text data (that is, graphic data linked to the database), I used this link to implement those operations, which could not be carried out in traditional cartography.

It was possible to apply the same query to the database, to drawings, and conversely, to give the database intuitive expression of drawings.

ArcheoGis allows the analysis of data stored, through many criteria, and it always allows the display of the graphic results of the analysis.

The potentiality I was dealing with, was achieved thanks to the project and the data structure, performed in the way already described, and also, thanks to the SML program.

SML (Simple Macro Language) is similar to many high-level programming languages. SML is an interpreted language. Every command line, entered from an SML file, is interpreted by the SML processor, which performs variable substitutions, logical branchings and looping operations, before the command is executed by the current ARC program. SML is a highly flexible language. I combined host, operating system commands, Arc/Info commands, and SML elements, to perform complex operations.

Employed macro (SML file), are a sequence of operations, consisting of the following steps:

- Selecting the stratigraphic units, which have the required characteristics, by the "select" operation, for attributes (that is, selecting a subset of features from a coverage using logical selection criteria, that operate on the attributes of the coverage feature [e. g., Harris LT 9]). Only those features, with attributes meeting selection criteria, are selected.

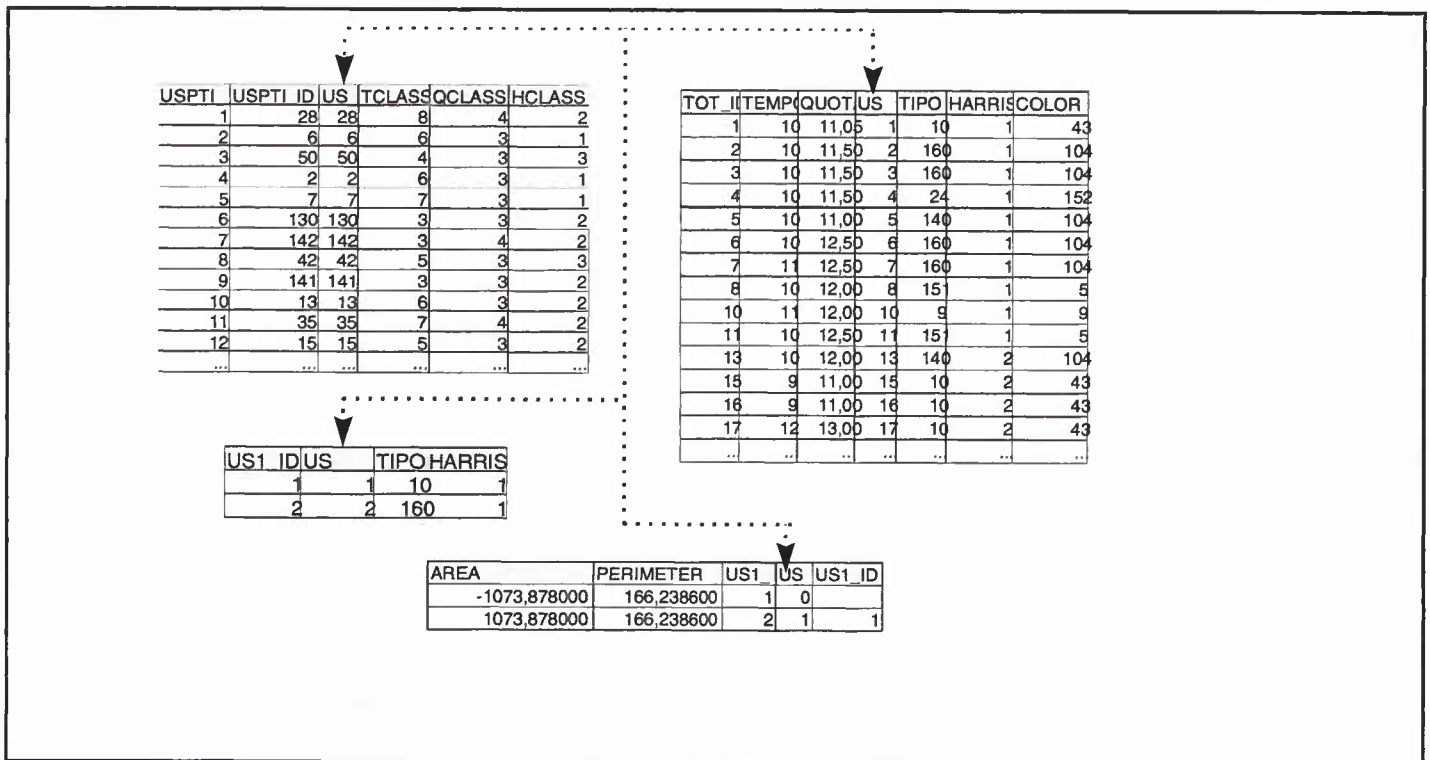


Fig 4

- Recording the resulting entities onto a text file, whose name is significant, with respect to the query.
- Display the stratigraphic units, resulting from the query, by the "read" operation on the text file.

In order to make this process systematic, I built a dictionary of significant file names for practicable analysis, e.g., "phase1" was the name of the file, in which stratigraphic units related to the first phase were recorded, "phase2" was the name of the file, in which stratigraphic units related to the second phase were recorded, "one" was the file name, in which stratigraphic units related to the first level of the Harris matrix are recorded, etc.

For statistical and classification processes, I used "Class" and "Statistic" Arc/Info commands, to analyze attribute information for the selected features.

The "Statistic" command generated summary statistics, for an item in the selected database file.

The "Class" command established numeric classifications, that could be used to assign symbols to coverage features.

Classifications were based on archaeological data, so feature class was determined by the stratigraphic units.

The attribute, on which classification was made could be chosen among: "Harris", "Quote", and "Time".

The categories, resulting from the classification process, were automatically stored in the database, through HCLASS, QCLASS, and TCLASS attributes.

The results could be displayed graphically, using an assigned class value for each feature.

Different classes were characterized by different colors, and the presence of a legend gave us the number (in percentage), of stratigraphic units, belonging to each class (fig. 5).

It was possible to carry out a chronological analysis (that is, phasing the site object of study, operating on the attributes, "Harris" and "Time"), as well as being possible to form hypotheses on types of structures, operating on the attribute, "Type".

If I wanted to apply this classification method for "phasing a site", I chose as an input item, "Harris", inserting as "break points", the levels of the Harris matrix, useful to determine a chronological phase.

In the case under observation (Villa Rufolo, Ravello), the Harris matrix had thirteen levels; if I wanted to verify the hypothesis, concerning the existence of three chronological phases, I chose "three", as the number of classes, and inserted "eight" and "eleven", as "break points". The percentage of classes, to which the resulting data belonged, let us know, among other information, the phase, when most of the structures of the Villa were built.

#### Presenting the results of the analysis

Design and layout must be considered, when producing output: a beautiful map helps to convey the intended message, with greater impact.

The tool kit, Arcplotw of Arc/Info, was used to fulfill mapping needs. Arcplotw provides full cartographic output capabilities, for Arc/Info, from simple screen display to high quality, cartographic plots, for report and presentation.

To display the various stratigraphic units, with a fixed texture, and to join them, with their respective legend, I used a lookup-table.

A lookup-table is a special, tabular data file, associated with a particular feature attribute table, containing additional attributes, regarding features beyond those, stored in the feature attribute table. For each unique, attribute value, there is a corresponding record in the lookup-table, with a specific symbol number. Lookup-tables offer several advantages. First, I could use any symbol to represent the attribute; it was easier to change symbols, if I wanted to change the look of my map. To reduce data storage, rather than storing the various symbols, with each record, in the attribute tables, I needed to store the symbol, only once, for each item value in the lookup-table.

ArcheoGis is characterized by the possibility to overlay and combine more stratigraphic units, according to analysis processes. It was for this reason, that I chose to associate not-filled textures, with different types of stratigraphic units, in order to pick the shape of the various coverages, even if they were overlapping.

Finally, I built a graphic user interface, consisting of a simple menu-driven application. This made it easier for the inexperienced Arc/Info user, to access the geo-archaeological database I developed, and to display and query information about the archaeological site object of study.

For example, selecting the label "localizza" on the "reperti" menu, the marker points would be displayed in the places

where artifacts had been found (fig. 6); the artefact design will be displayed by click on one of these markers (fig. 7).

### **Results**

In conclusion, it is possible to maintain that Archeo/Info, besides the management, integration, and manipulation of archaeological data settled for the territory under investigation, allows the combination of various informative levels, which, in turn, produces new information.

This knowledge is usually achieved, both through techniques of topic overlapping, and through statistical and classification processing, on the whole of the stratigraphic units, for the studied site.

The next step will be to pay great attention to checking the results of statistical and classification processes. Moreover, I am going to follow this model, on more archaeological sites, in order to exploit GIS potentialities, and to compare, not only excavation data, but also the geomorphological and geographical features of various sites.

### **List of Figures in CD-ROM.**

**Fig. 1 and 2.** Villa Rufolo, Ravello (Italy).

**Fig. 5.** "ArcheoGis" Graphic.

**Fig. 6**

**Fig. 7**