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# A WEB GIS FOR PROMOTING ARCHAEOLOGICAL ASSETS

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## Abstract

Recently, the challenge of making geographic data available for analysis tasks also on the Internet has motivated the development of Web Geographic Information Systems (Web GIS). This term is referred to all the software products and services that allow geographic information to be accessed in different ways, by adopting Web technology.

In this paper we describe a Web GIS developed for handling and promoting information about archaeological sites. In particular, the experimented system is one of the goals of a wider research project, resulting from a long term collaboration between the Department of Mathematics and Computer Science and the Department of Cultural Heritage of the University of Salerno. The aim of such a research activity is the development of an information system enabling heterogeneous users to exploit GIS capabilities and Web accessible data. The interaction between the two departments arose from the need of archaeologists who required a working tool that would allow them to manage the collected data in an integrated way that is not affected by any particular a priori interpretation.

The prototype has been experimented to build a vectorial representation of Fratte Hill archaeological site (in the area of Salerno) within its physical context that considers all the stratigraphic information and the whole sequence of archaeological deposits.


**Keywords**: geographic information systems, web applications, archaeological site, spatial analysis, stratigraphic units.

## 1. Introduction

Cultural organizations are devoting increasing attention to Geographic Information Systems (GIS) as means for preserving the world artistic and historical heritage. As a matter of fact, GIS technology effectively integrates usual database operations, such as queries and statistical analysis, with visualization and spatial analysis techniques. This provides a complete approach to the efficient and correct monitoring and analysis of geographic information [2, 4, 8, 9]. The application fields of GIS technology vary from natural environment conservation to analysis and planning of antropic environments, to studies on social, economic structures, and to archaeology [3, 7]. In all cases, GIS allow for the construction of maps and the manipulation of integrated information, as well as for scenarios visualization. Effective solutions to complex problems can be developed by GIS by relating geographic data to each other and embedding them in new structures. Such solutions can be expressed in a qualitative/quantitative form, and visualized in terms of maps answering to specific requirements.

Recently, the challenge of making geographic data available for analysis tasks also on the Internet and hence accessible from all over the world, has motivated the development of Web Geographic Information Systems (Web GIS). This term is referred to all the software products and services that allow geographic information to be accessed in different ways, by adopting Web technology [10]. This enables Web users to exploit GIS applications in order to search widely used geographic data sets, and to enhance GIS applications with new functionality, with no need to purchase expensive software products. The aim of supporting the common Web user in complex GIS analysis tasks, has challenged developers with the design of user-friendly interfaces, which would allow him/her to effectively interact with a Web GIS, after some short-term specialized training.

In the present paper we describe a Web GIS developed for handling and promoting information about archaeological sites. The benefits coming from the use of GIS in archaeology are widely recognized [1, 6, 11]. The management, analysis and research of cultural resources is enhanced by the powerful set of tools provided by GIS applications. Thanks to the easy construction of different layers related to a certain geographic layer, archaeologists can analyze the impact on the site location of different variables, like soil type, topography or distribution of superficial water streams. With GIS prediction can also be made about the location of sites, based on information about known sites and looking for areas that have matching characteristics [12, 13]. Moreover, the degree of accuracy of information about archaeological sites and cultural features is notably increased by integrating directly into GIS the data collected with Global Positioning System receivers. If archaeologists are allowed to integrate data coming from their traditional excavation activity with GIS, they may come to discover new important information about human kind evolution.

The aim of the present research has been to integrate the benefits coming from the use of GIS in Archaeology with the power of Web technology. A long-term collaboration with archaeologists of the Department of Cultural Heritage, at the University of Salerno, has lead us to design a Web GIS satisfying their need to perform analyses of the data collected from stratigraphic sites, by requesting remote GIS operations able to integrate those data with information derivable from the Internet. The idea of divulging the collected data on the World Wide Web, to make them available to archaeologists for further processing, is also meant to have beneficial side effects on diffusion of knowledge about world's cultural heritage among common people. As a matter of fact, an archaeological Web GIS may become a valuable tool in educating people about the past, by convincing them about the need to preserve our historical heritage and demonstrating that archaeological sites are a limited resource. Thus, special focus has been put on the design of a visual environment that provides Web users with a friendly and usable interaction method. As a result the user is provided with an intuitive visual multimedia environment where he/she can easily access the heterogeneous and distributed archaeological data available on the Web.

The paper is organized as follows. Section 2 recalls some basic elements of the archaeological methodology adopted to accomplish the data analysis. In Section 3 the geographic database design is described, by illustrating the framework of both spatial and descriptive components. Section 4 gives details about the Web GIS development and implementation. A sequence of screenshots illustrate the visual environment for data management and the query formulation for descriptive information searching. Also some mapping functions are described. Final remarks conclude the paper.

## 2. The application domain: Fratte Hill archaeological site

In the last years, the experience acquired on the Etruscan sites of Campania by the archaeologists of the Department of Cultural Heritage provide us with the basic information to accomplish the requirement analysis of the expected system.

The initial phase aimed to recognize the basic features of information to deal with. As known, the archaeological stratigraphic investigation locates on the field the widest evidence variety of an ancient anthropic presence. Every activity is recorded as a stratigraphic unit (US), whose significance can be reassembled through its costituent elements. US represent the smallest elements that a stratigraphic investigation locates on the field and, from this point of view, their usefulness is twofold: they both provide experts with a basic reference layout for ancient activity interpretation and represent the cell of registration for the acquisition of archaeological information.

Each US featuring into the area of interest of Fratte site has been evaluated with respect to different types of analyses: nature, location, shape, destination, materials, etc.. Every US has been then associated with a unique identifier, made up of a four digit number. The first digit represents the zone where the US has been discovered, the last three digits refer to the US identifier within a catalog. As an example, US 3001 refers to the first stratigraphic unit of the third zone. In turn, zones locate areas of archaeological structures and layers, which are homogeneous for function, space and chronology. They represent material cells that reproduce the site organizational framework.

In the archive organization, archaeologists aimed to preserve the original meaning of the filing methodology. The goal was to obtain a seamless data migration from a relation-based system adopted during the identification of archaeological evidences, to a different management, filing and searching system. That is to say, stratigraphic units act as the core of a complex structure, where the existence of each data is tightly dependent on and related to a specific US. That is why recording procedures are the same both for US and for documents related to ceramical findings, clay and metal objects, palaeobotanical and osteological findings,.

## 3. The geographic database

Databases play a fundamental role in the exploitation of GIS technology in the archaeological domain. They allow a total and lossless management of archaeological records, which can be modelled according to a basic and unique structure, so allowing data migration from different GIS solutions.

Basically, an archaeological database represents a linkage of different data types. It contains data concerning the site and its features (geology, morphology, soil conditions, locations, coordinates, projections, ect..) and documentation about archives resources, references, chronology, etc.. In excavations, each unit has a number of attached attributes, size of the unit, artifacts located within the unit, proximity to other units, etc. When a GIS embeds an archaeological database, it operates exactly the same way: each digital unit is attached to the database with a number of fields, it allows quick and easy access to the attributes of each unit, it also allows a graphical comparison of units across space. Based on this dataset, a wide range of searches can be performed and many queries can be formulated. A typical query searches for descriptive data and its result is visualized in terms of spatial features. While, a spatial query is based on spatial operators, which involve local, focal or global relationships. It is also important to notice that such kinds of queries are usually followed by spatial analyses performed on the cartographic system, which is structured during the geographic database design task. Thus, the quality of data featuring into the database affects the query management in the GIS itself.

As for the site in Fratte, archaeological data collection and analysis have been performed with the support of expert users working on the excavation. A proper documentation has been produced demostrating that geographic data featuring into the expected database represent a typical model of an archaeological excavation. However, the underlying schema has been developed in order to characterize only some features of the real-world, namely features which are useful for specific analysis tasks. As a metter of fact, data analysis has focused on requirements to be taken into account during the spatial query processing emphasizing both elements of interest in terms of entities and features, and methodologies adopted for data acquisition and interpretation.

Once the requirement analysis has been accomplished, we designed the geographical database, following conventional guidelines [5]. The output of the first stage of the conceptual design consists of a set of descriptive specification about the archaeological site. This task has been accomplished with the collaboration of a group of archaeologists, who described their needs about the geographical information management.

Figure 1 illustrates the conceptual schema which describes the set of objects and processes characterizing the domain of interest. This schema has been modelled according to the graphical notation of an EER diagram. As an example, the "Prelievi" (drawing of samples) entity is represented by a set of attributes, such as description, location and number of litres. This entity is used to perform chemical analyses of materials. The "US" entity, which is used for a stratigraphic study of soil, is represented as a polygon in terms of shape and coordinates, and attributes, like zone and ID. The second step of the database design aims to derive a logical schema. In this case, a relational model has been applied and some normalization guidelines have been followed in order to optimize query processing. Finally, during the physical design a complete description of the internal organization has been derived, in terms of files, tables, indexes, attribute names and dimensions, data topology, data resources and acquisition techniques. Such data have been structured in a system catalog, useful for documentation tasks.

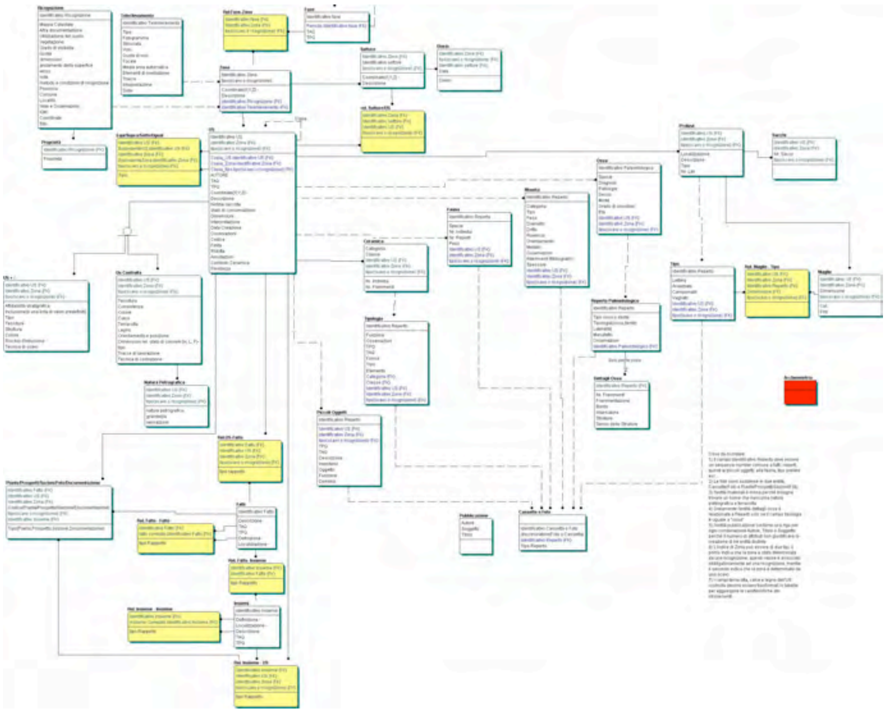

Fig. 1: The EER schema of the geographic database

During the organization of excavation data, it was also fundamental to follow the archaeological stratigraphy principles. As a matter of fact, positive and negative stratigraphic units should be distinguished according to both their conceptual differences and their geometry. The former set describes surfaces which can be represented by polygons. The latter describes surfaces devoid of material consistency, which can be represented by lines. Based on these observations, an open and functional spatial model has been defined, which satisfies specific requirements of the involved thematic realities.

Our model is based on a macro-map, which is made up of several layers, built without any a priori interpretation process. Such a vector map guarantees the ability of globally viewing the site and its content. Moreover, in order to both examine smaller areas and perform a more analytical approach, new zonal composite maps have been added as single georeferenced layers. Finally, some themes have been created which collect semantically- and spatially-related objects.

The resulting geographic database is hence made up of two joint components: a spatial component, which describes the geography of the archaeological area (position and shape), and a descriptive one, dedicated to the site characteristics and quality. Figure 2 shows the cadastral map, with details about excavation areas.

Fig. 2: The map of the archaeological site in Fratte

In Figure 3 some corresponding properties are organized, such as stratigraphic units, soil use, etc.. It is woth to notice that such components are tightly integrated in order to derive information regarding all the features of excavation documentation.

| Shape | Id_zone | TIPO_SCAVO_O_RICOGNIZIONE | ID_RICOGNIZIONE | ID_TELERILEVAMENTO | DESCRIZIONE |
|---|---|---|---|---|---|
| Polygon | 601 | SCAVO | ricognizione4 | telerilevamento14 | Assente |
| Polygon | 6 | SCAVO | ricognizione11 | telerilevamento15 | Assente |
| Polygon | 4 | SCAVO | ricognizione23 | telerilevamento16 | Assente |
| Polygon | 600 | SCAVO | ricognizione12 | telerilevamento17 | Assente |
| Polygon | 301 | SCAVO | ricognizione45 | telerilevamento18 | Assente |
| Polygon | 3 | SCAVO | ricognizione8 | telerilevamento13 | Assente |
| Polygon | 300 | SCAVO | ricognizione98 | telerilevamento19 | Assente |
| Polygon | 700 | SCAVO | ricognizione12 | telerilevamento20 | Assente |

Fig. 3: Some properties associated with geographic objects

## 4. A Web GIS for Fratte archaeological site

A Web GIS system represents the tool that enables to retrieve and process in a uniform way spatial data which are positioned in heterogeneous and geographically distributed environments and platforms. In order to provide such a functionality the initial requirement analysis has suggested the development of three related applications. Namely,

an excavation platform (site and maps);

a descriptive database (management system for stratigraphic unit archives and ruin samples, etc.) and spatial component (geometric objects and topology);

a graphical user interface for data population, update and visualization.

First of all, following the guidelines of the design task, the area of interest has been georeferenced, according to the zone plan. This task has been accomplished with the support of an architect, working on the area. This procedure allows both a rapid recognition of structures composing the site, and a fast location of stratigraphic units on surface subparts.

The Web GIS has been experimented on the Zone 3 of the site in Fratte. The Zone 3 has been analysed with respect to the landscape and settlement context. Stratigraphic data have been layered, so representing the whole chronological reality of archaeological deposits. A large amount of US have been first inserted by a vector digitalization procedure, then they have been classified in terms of type, chronology, building material, samples, etc.. In this way, each graphic shape has been associated with the corresponding set of values, so representing a geographic object. Moreover, a detail card containing multimedia documents has been associated with each US. Data population has been accomplished with the support of the equipe of archaeologists involved in the experimentation. Figure 4 shows the Zone 3 (a) and vectorialization of its US (b).

 

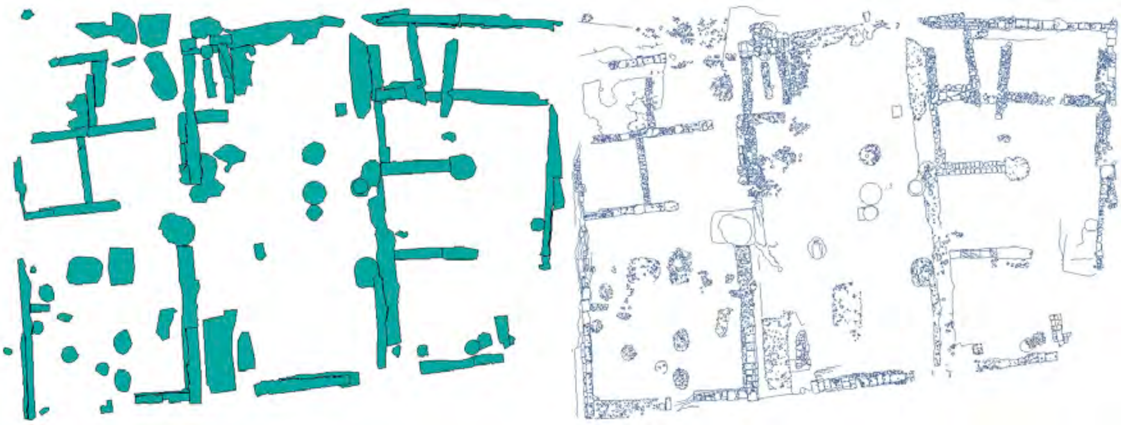

Fig. 4: (a) The Zone 3. (b) Stratigraphic units

As for the graphical user interface, the visual design of the Web GIS interface required a great care to assure that users can understand and make use of the information and functions provided by the system. As a matter of fact, the high potentiality of these systems has brought on the scene new typologies of users, including domain experts and end-users, whose requirements and skills are quite distant from programmers' ones. Hence, in order to allow non-programmers to exploit their own knowledge to learn the use of the available software many efforts has been devoted to improve the usability of GIS through the design and the development of graphical interfaces.

In general, the interface design requires the definition of the conceptual entities corresponding to the application domain, of their possible relations and behaviours. For each of these aspects, we have defined the corresponding visualizations and interactions required by the user. Then, we have distinguished the domain aspects from the presentation and the manipulation ones, preserving the dependencies among them precisely, in order to keep coherent the interface and the application states.

### 4.1 The visual environment

Using the Web GIS requires an HTML browser on the client side. At the present, it can be visited at http://www.dmi.unisa.it/research.html.

After an initial page describing the archaeological site and some collaborations in progress, the environment appears as shown in Figure 5. It consists of three frames, the central area contains the map of interest and some buttons recalling typical GIS functionality (zooming, panning, selecting, identifying, thematic layers, etc..). On the left side, an interactive area is shown, when queries can be posed by setting parameters that are meaningful to domain experts (historical period, US type, building materials, etc..). The query result is shown on the right side, where US satisfying the query are listed.

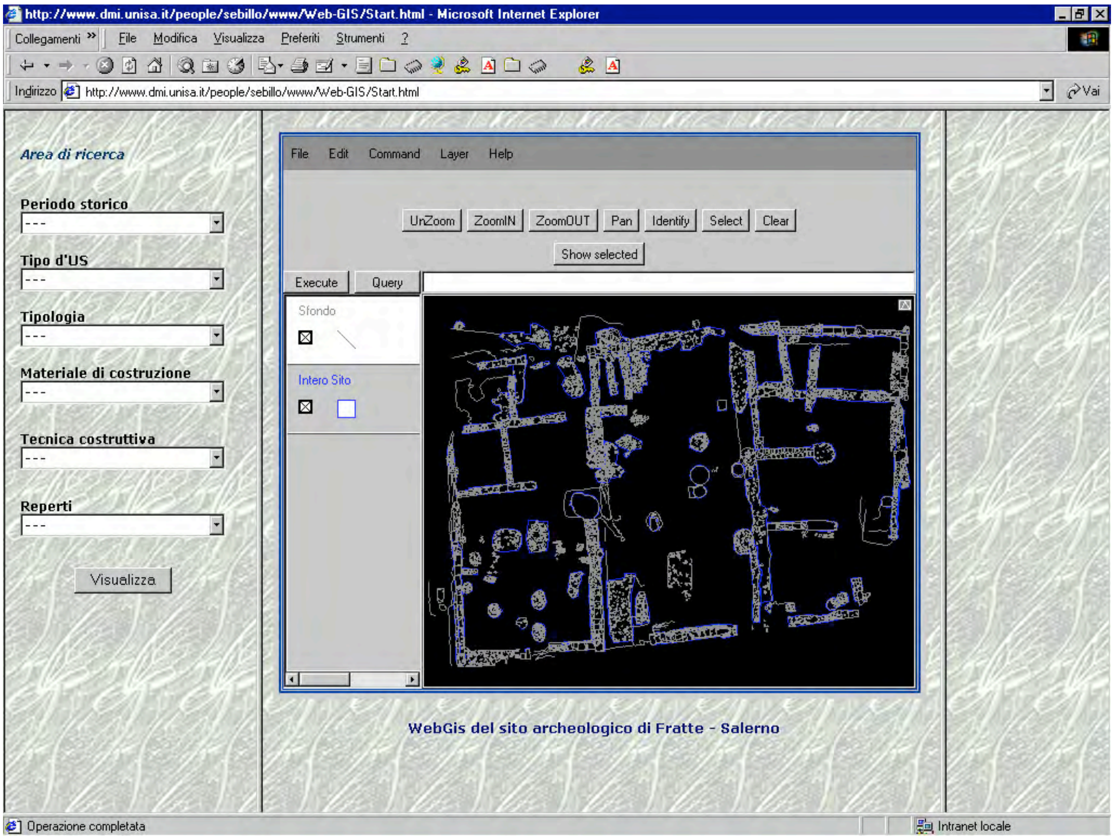


Fig. 5: The visual evironment of the Web GIS

Figure 6 illustrates a deeper view of the central frame, where two basic layers are activated, namely 'Sfondo' (backgroung) and 'Intero Sito' (the whole site). The former layer represents the spatial component of the archaeological site. It is useful to provide users with a global site view. The latter contains the site US and can be used to pose GIS queries. Both of them are represented as shapefile whose descriptive components are .dbf files.

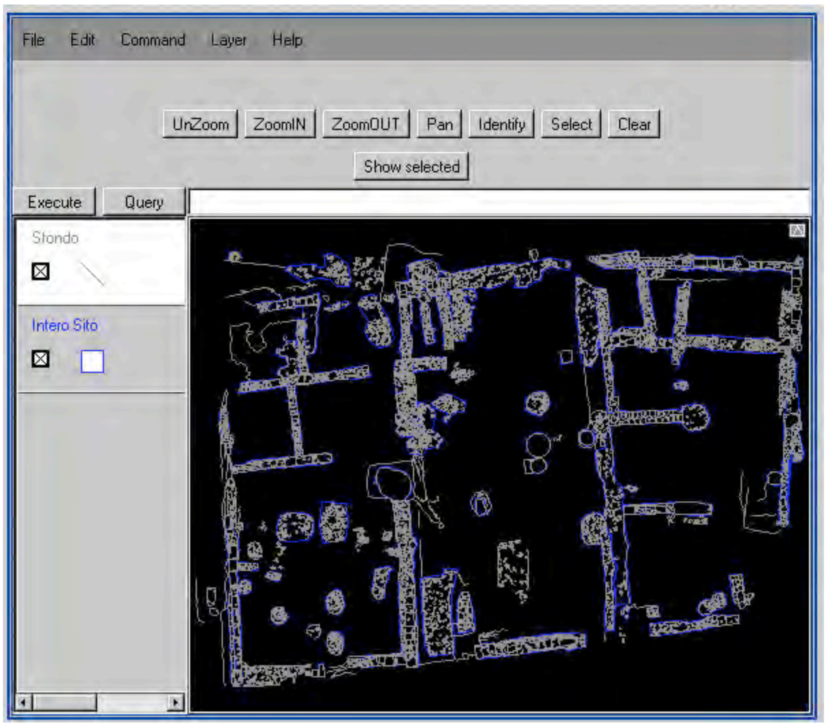


Fig. 6: A detailed vision of activated  layers (sebillo_fig6.jpg)

## 4.2 Query formulation and spatial analysis

Following guidelines for designing the Web GIS allowed us to define categories of geographic objects, basic for layer interpretation. Along this line, logical operators and query formulation are meant to select and visualize sets of US that allows users to understand either an historical period or a single event of a more complete scenario.

The Web GIS we propose provides users with different modalities of query formulation, according to geographic components to be investigated. Typically, users are allowed to pose alphanumeric queries in order to search for spatial components of geographic objects. Similarly, descriptive information can be obtained by selecting spatial features. Figure 7 shows a descriptive query which selects US with ceramic materials, dating back to Roman historical period.

 

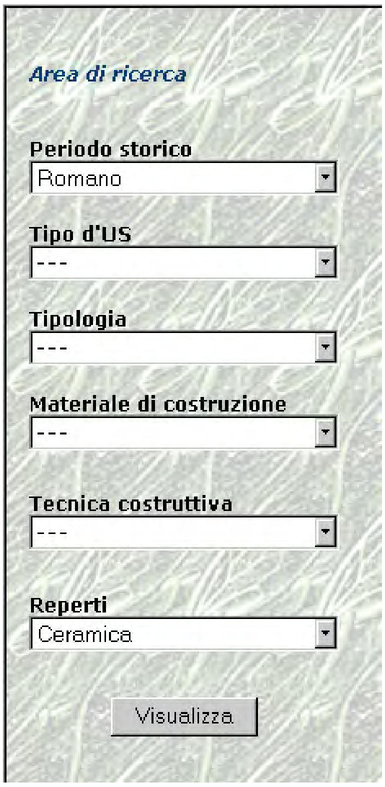


Fig. 7: A descriptive query

After the query execution, the result is shown on the map, corresponding to the yellow US, as shown in Figure 8.

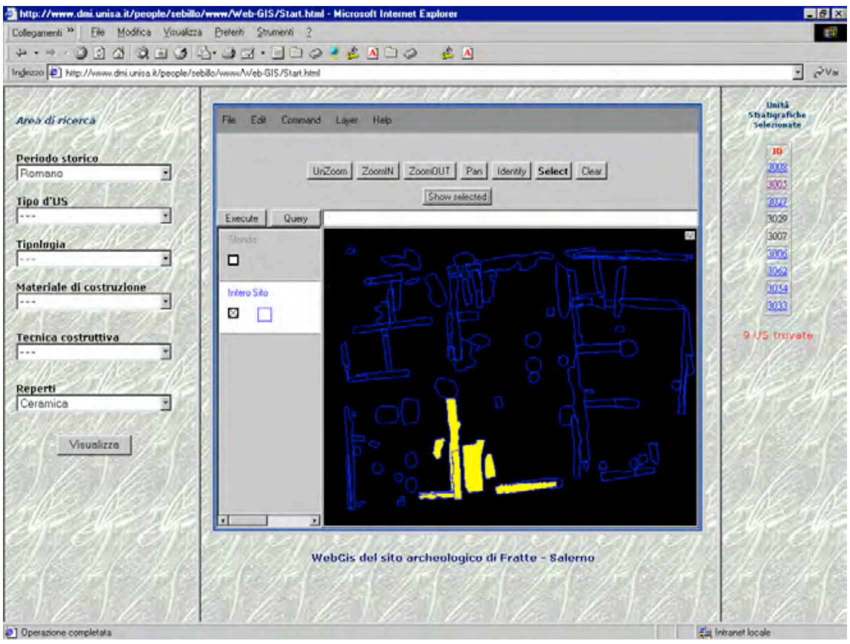


Fig. 8: The result of the query depicted in figure 7. The yellow US belong to the answer set

Users can also zoom and pan the area of interest, as shown in Figure 9. On demand, more detail can be obtained by selecting a US from the list appearing on the right side. A detailed card appears as an HTML page, as shown in Figure 10.


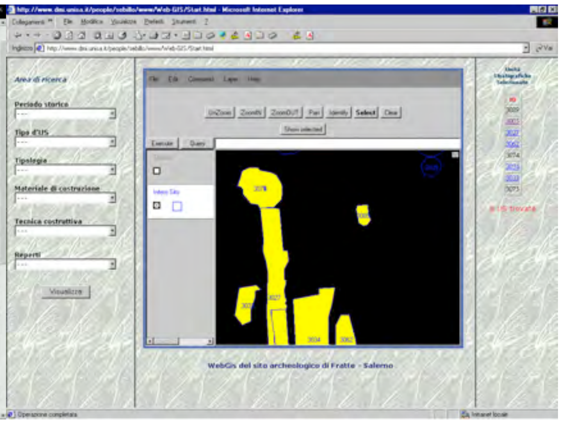

Fig. 9: Typical GIS functionalty operating on the map Fig. 10: A detailed card associated with the corresponding US

Besides queries that select US satisfying descriptive requirements, users can also select an area of interest in order to derive information about the involved US. In Figure 11 a spatial query is shown, the resulting US are listed on the right side and more detail can be visualized, on demand.

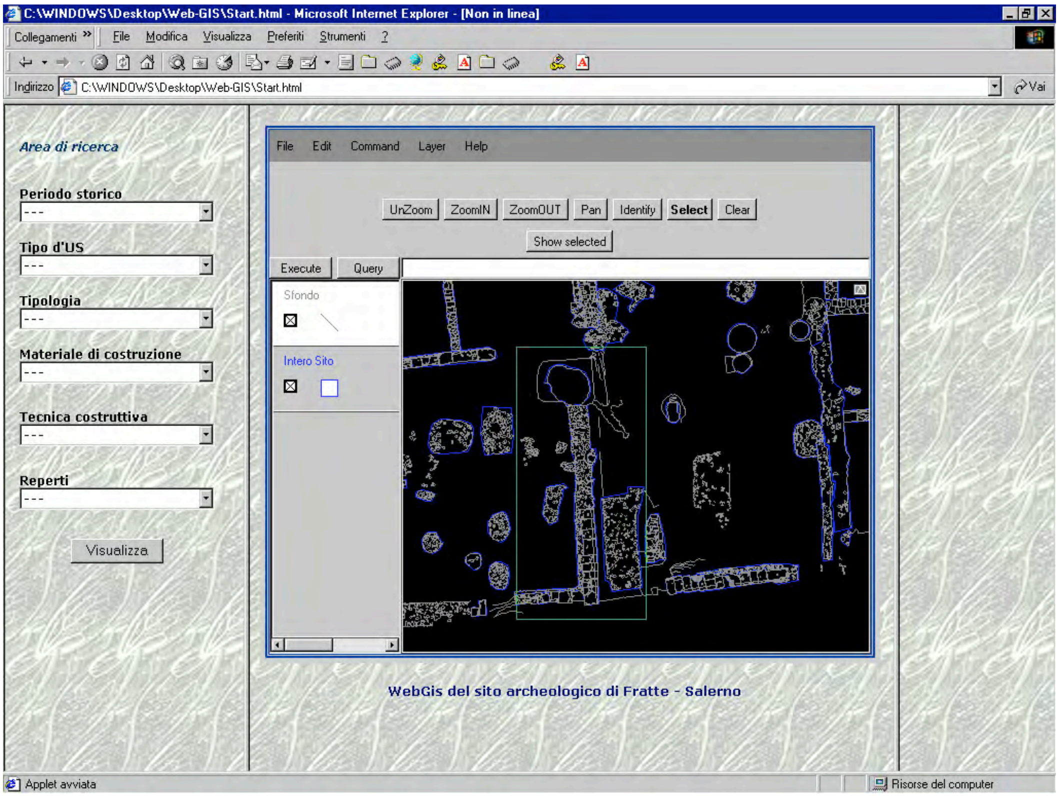


Fig. 11: A spatial query

Finally, users can choose to select a US, directly on the map, by using the identify function which invokes the corresponding detailed card. The identification is helped by visualizing the labelling of every US, as shown in Figure 12.

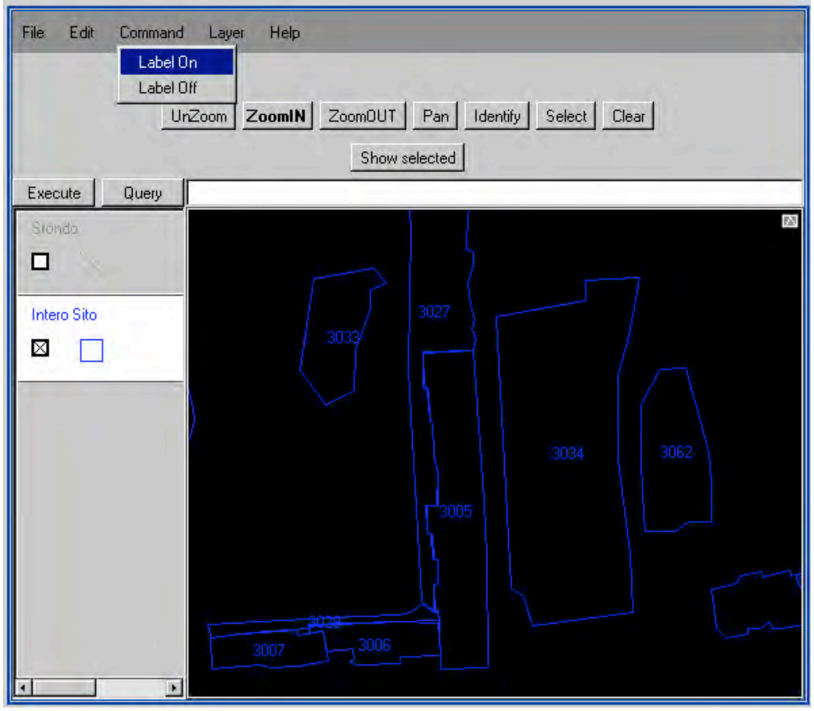


Fig. 12: Label activation for US identifying

The core of the Web GIS is a Java applet. From a technological point of view, this feature guarantees a platform-independence, which is an important property when a large amount of users is expected to be involved.

The Java applet provides mechanisms to customize the Web GIS. Users can:

add new layers and themes;

change colours for data visualization;

add pre-defined queries;

change visualization scale.

An external file can also be run, which contain functions that the Java applet can invoke during its life-cycle. Such a file is associated with the applet through the parameter setting 'cmdfile' as follows:

<param name="cmdfile" value="US.cmd">

As an example, the 'US.cmd' file contains the function for US indentifying and table visualizing after a query creation. The function statements can also be interpreted and executed by users themselves.

## 5. Conclusions

In the archaeological domain many efforts are devoted to obtain an effective integration among GIS applications and Web technology. As a matter of fact, archaeologists have realized that they can get benefit from Web GIS, as a valuable tool in their studies.

In this paper we proposed a Web GIS whose aim is to support domain experts to perform decision making and scenario simulation. The prototype is developed by using the Java object oriented programming language and it provides users with the basic functionality for the map and layer management. Moreover, it allows users to pose both textual queries about find features and spatial analysis concerning search location and topological relations.

The prototype has been experimented building a vectorial representation of Fratte Hill archaeological site (in the area of Salerno), where specialized operators and trained archaeologists have performed on-site data acquisition.

The result is a GIS tool that, despite of its internal complexity, allows non-expert users to simply and quickly perform several tasks, like general or detailed context overview, data elaboration, and thematic maps plotting. It also allows archaeologists to both integrate data and guarantee a coherent documentation between existing data and results derived by this new research activity. The need for consistent documentation is especially felt when different équipes of researchers perform excavations on the same archaeological sites. The information involved in the Web GIS can be related to the investigation results, and to the published/unpublished material resulting from excavation sites explored in the nineteenth century and never presented in a unitary fashion.

Moreover, it is also accessible to Monuments and Fine Arts Agencies, to Local Tourist Offices, to domain experts and, last but not least, to occasional end users, who access the Web to retrieve information about the cultural heritage of the territory.

## References

Aufaure-Portier M.A., (1995). A High Level Interface Languages for GIS, in Journal of Visual Languages and Computing 6, pag.167-182.

Biallo G. (2002). Introduzione ai Sistemi Informativi Geografici. MondoGIS.

Chrisman N. (2002). Exploring Geographic Information Systems – Second Edition. Wiley

DeMers M. N. (2000). Fundamentals of Geographic Information Systems - Second Edition. Wiley.

Elmarsi R. and Navathe S. B. (1994). Fundamentals of Database Systems. The Benjamin/ Cummings Publishing Company.

Forte M. (2002). I Sistemi Informativi Geografici in archeologia. MondoGIS.

Laurini R. (2001). Information Systems for Urban Planning, A Hypermedia Co-operative Approach. Taylor and Francis, Londres.

Longley P. A., Goodchild M. F., Maguire D. J., Rhind D. W. (2001). Geographical Information System Principles - Second Edition. Wiley.

Longley P. A., Goodchild M. F., Maguire D. J., Rhind D. W. (2001). Geographical Information Systems and Science. Wiley.

Plewe B. (1997). GIS Online: Information Retrieval, Mapping, and the Internet. Santa Fe, OnWord Press.

Santoriello A., Scelza F. (2000). Un sistema Informativo Archeologico: l'Applicazione del Syslat a Fratte di Salerno. Archeologia e Calcolatori, n. 11, pp. 69-94.

M. Sebillo, G. Tortora, M. Tucci and G. Vitiello (2001). Supporting the Promotion of Historical and Cultural Treasures with a GIS-based Visual Environment. Procs of the Int.l Cultural Heritage Informatics Meetings - Cultural Heritage and Technologies in the Third Millennium, ICHIM 2001, Milan, Italy 3-7 September, 2001, pp. 543-558.

M. Sebillo, G. Tortora, M. Tucci, G. Vitiello (2001). Verso un Ambiente Visuale Web-GIS per la Catalogazione e la Pubblicazione di Dati Archeologici. SIE Società italiana di ergonomia - Simposio su Human-Computer Interaction (HCITALY 2001), Firenze, 26 Sett. 2001.