Supporting the Promotion of Historical and Cultural Treasures with a GIS-Based Visual Environment

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ABSTRACT
Applying geographic information technology in the area of cultural heritage has recently raised a great deal of interest. Indeed, several geographic information systems (GIS) have been developed targeted to applications like tourism promotion, archaeological investigations and monument preservation. In spite of GIS high potentiality, users are often faced with the implicit complexity of data and are forced to become familiar with the related concepts. This is also true in cultural fields where final users are supposed to be domain experts and researchers, who are usually not familiar with GIS technology. Visual languages represent a promising means for allowing unskilled users to query geographic databases. The visual environment *MGISQL* can be used on top of an available GIS able to store and retrieve geographic information. A visual approach allows us to simultaneously capture the spatial and the thematic components of geographic data, thus providing users with further intuition about the semantics of those data in the real world. In this paper we present an experimentation carried out with the *Visual Salerno GIS (ViSaGIS)*, which has been designed to promote the cultural treasures located in the area of the city of Salerno (South of Italy). Our experiment shows how the *MGISQL* environment can be successfully used to process artistic and archaeological information.

KEYWORDS: Geographic information systems, visual languages, tourism promotion, monument preservation.

INTRODUCTION

Cultural organizations are nowadays paying increasing attention to Geographic Information Systems (GIS) as a means to manage and preserve historical and artistic legacy. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. The use of this technology is therefore expected to overcome the difficulties traditionally encountered in keeping hand-drawn maps and tables up-to-date. As a matter of fact, several geographic information systems have been developed targeted to applications like tourism promotion, archaeological investigations and monument preservation. In spite of GIS high potentiality, users are often faced with the implicit complexity of data and are forced to become familiar with the related concepts. This is also true in cultural fields where final users are supposed to be domain experts and researchers, who are usually not familiar with GIS technology. For that reason, the recent trend of developers has been to provide GIS with graphical user interfaces (GUI) based on international standards like Windows, whose design is facilitated by the availability of interactive graphical editors. Examples of products following this approach are *ARCVIEW* from Environmental System Research Institute [15], *SPANS MAP* from TYDAC [16], and *MGE Project Viewer* from Intergraph Corporation [17]. Users of a GIS provided with a GUI are allowed to focus on specific issues of the application, since however complex commands are filtered through the widgets characterizing the interface (see, e.g, [6]). Yet, when trying to retrieve and manipulate spatial data, the need arises to establish an easier and more adequate interaction between the man and the machine performing the powerful functionality of a GIS.

Recent studies on visual languages show that they represent a promising means for allowing unskilled users to query geographic databases, and to interpret and possibly reuse recorded queries [1, 13]. Systems like *Cigales* [2], *GISQL* [5] and the *GIS Wallboard* [8] are mainly based on the definition of graphical representations for the spatial properties associated with the geographic data manipulated, and for the involved spatial operators. Spatial properties are referred to the geometry of the geographic data and to their topology, which describes objects' relative positions. When trying to add user-friendliness to GIS, the association of visual descriptions to such features seems to be quite a natural step. As a matter of fact, many systems have been primarily targeted for visually querying spatial features of GIS data (see also [10, 14]). On the contrary, the information about the real world phenomena that such data represent, is often given in terms of sets of alphanumeric attributes, known as *map themes*. This can become critical in fields like cultural heritage management, where GIS users might also be 'end-users', namely people like historians, archaeologists, and archivists, who are not familiar with programming processes and are at the same time expected to perform complex tasks and come to important decisions with the support of GIS technology. The goal of our present research has been to provide those users with further intuition about the data processed, by means of a visual query language, which also describes the semantics of those data in the real world. The *Metaphor GIS Query Language* (*MGISQL*, in the following), first introduced in [12], can be used on top of an available GIS able to store and retrieve geographic information. In the present paper we show how this visual environment can be successfully used to process artistic and archaeological information. In particular, we describe the experimentation carried out with the *Visual Salerno GIS* (*ViSaGIS*), which uses *MGISQL* to promote artistic and archaeological treasures located in the area of the city of Salerno (South of Italy).

The paper is organized as follows. Section 2 provides some preliminary notions, needed for readers not familiar with GIS technology. In Section 3 the basic concepts are recalled that underlie the visual query formulation in *MGISQL*. Section 4 contains an overview of the visual environment hosting *ViSaGIS* and a description of its practical use. Section 5 concludes the paper with some final remarks.

BACKGROUNG

Geographic information is typically concerned with spatially referenced and interconnected phenomena, such as towns, roads, as well as less precisely defined regions with environmental attributes, such as woodlands. Such real world phenomena can be graphically represented by a structured set of spatial and descriptive data, which form a *geographic database*. Indeed, in a geographic database, spatial data are represented by visualizing the geometry of their elements in a map. The basic geometric elements are points, lines and regions, which contribute to create more complex objects by applying some topological primitives. Descriptive data are instead organized as attributes of relational tables by an underlying DBMS. Thus, we can distinguish among merely *alphanumeric* data, merely *spatial* data, which are uniquely identified by their geometric representation, and *geographic* data, where spatial features are associated with alphanumeric attributes. Figure 1 illustrates the alphanumeric and the spatial components of a geographic data which refers to an archaeological site.

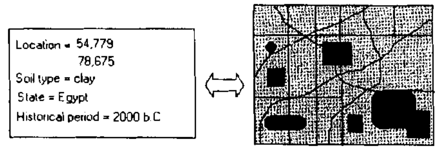


Figure 1. Geographic data

Geographic data processing is more complex than conventional structured data processing because of both the nature of geographic information itself and the type of retrieval and analysis operations performed upon it. A lot of efforts have been devoted to the task of geographic data manipulation. As a result, in recent years the field of *geograpkic information systems* (*GIS*) has quickly evolved. A typical GIS provides an integrated environment including tools for the input and manipulation of geographic information, a database management system, to help store, organize, and manage data, and tools that support geographic query, analysis and visualization [9].

Information about the world is stored in a GIS as a collection of *layers* that can be linked together by geography. In particular, layers are organizational schemes in which all data of a particular level of classification, such as roads, rivers or vegetation types, are grouped. They can be combined with each other in various ways to create new layers that are functionally related to the individual ones. Moreover, any association which relates each object of a layer to a set of attributes, is said to *realize a theme* and to *derive thematic layers*. For example, in an archaeological map, built-up area, census area, and aquifer represent some of its thematic layers (see Figure 2).

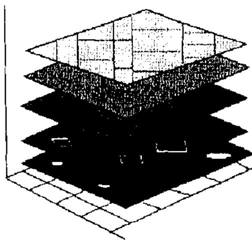


Figure 2. The thematic layers composing an archaeological map.

Thus, GIS provide methods for representing geographic data that allow the user to adopt conceptual models closely related to the source data. This implies an emphasis on the geometry and topological primitives that characterize surveyed data. There are two categories of geographic models encountered in commercial GIS, the *vector data model* and the *raster data model.* The former represents phenomena in terms of spatial primitives, or components, consisting of points, lines, areas, surfaces and volumes (see Figure 3). The raster data model represents phenomena as occupying the cells of a predefined, grid-shaped tessellation. It is commonly used to describe continuously varying features, but the kind of information which can be derived is very limited with respect to the vector data model.

While carrying out our research, we have focused on the vector data model, which is characterized by a more natural representation of the geometry and the topology of the surveyed data. In particular, we have based the formalism underlying *MGISQL* on the *9-intersection model* by Egenhofer and Herring [7]. It is a comprehensive model for binary topological spatial relations and applies to objects of type region, line and point. It characterizes the topological relation *t* between two point sets, A and B, by the set of intersections of A's interior (A°), boundary (∂A), and exterior (A^-) with the interior, boundary and exterior of B. With each of these nine intersections being empty ($\emptyset$) or non-empty ($\neg\emptyset$), the model has 512 possible topological relations between two point sets, some of which can never occur, depending on the dimensions of the objects, and the dimensions of their embedding space.

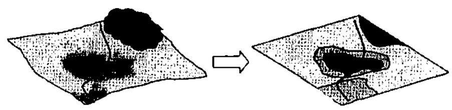
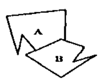


Figure 3. A vector representation for a geographic layer

As an example, let us consider the topological relation adjacent (between two regions A and B). it can be represented as follows.

A adjacent B $\Leftrightarrow$ 

$A^\circ \cap B^\circ = \emptyset$, $A^\circ \cap \partial B = \emptyset$, $A^\circ \cap B^- = \neg\emptyset$,

$\partial A \cap B^\circ = \emptyset$, $\partial A \cap \partial B = \neg\emptyset$, $\partial A \cap B^- = \neg\emptyset$,

$A^- \cap B^\circ = \neg\emptyset$, $A^- \cap \partial B^- = \neg\emptyset$, $A^- \cap B^- = \neg\emptyset$.

Spatial relations are used as a basis in the definition of *MGISQL* spatial operators. In the next section we recall the basic concepts that underlie the visual query formulation in *MGISQL.*

A VISUAL REPRESENTATION FOR GEOGRAPHIC DATA: THE *GEOMETAPHOR*

Visual languages are today being widely used as a means for reproducing the user's mental model of the data manipulated [4]. In particular, in the area of database systems, several visual query languages have been proposed, which relate the computer representation of the information contained in a database to the users' understanding of the database content [3]. When dealing with the information manipulated by a GIS, the definition of appropriate visual query languages becomes an especially challenging task. A study on computational models of spatial relations has revealed that human subjects tend to draw a geographic object by providing its geometric representation, while referring to its meaning in the real world, namely to the theme that the object describes [11]. This means that the two parts of a geographic data are intrinsically related in human minds. The visual approach we propose is based on the concept of *geometaphor*, a special type of visual description which is meant to simultaneously capture the double nature of geographic data, which are made up of a geometric component (needed to define the spatial relations) and a thematic component (referring to a real world entity). Figure 4 shows how geometaphors collect both aspects of a geographic data. The graphical part carries information about the underlying spatial element (its topology), while the icon recalls the descriptive part corresponding to the visual representation of the real world phenomenon which the GIS element refers to (i.e., the theme it describes). The topology of the involved GIS element is represented by associating with it the corresponding symbol. In particular, an elipse bordering its label is meant to represent regions, a line underlying its label is used to represent lines, and a bold dot near its label represents points.

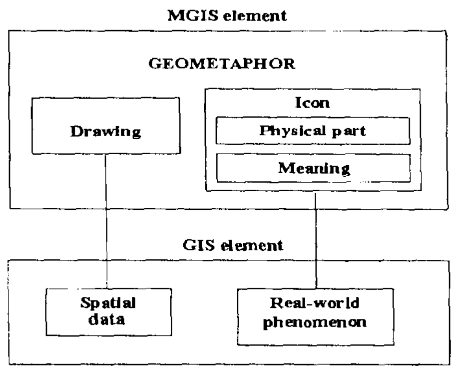


Figure 4. The geometaphor for a GIS data in *MGISQL*.

For example, the geographic data Church may be described as the geometaphor , whose components are displayed in Table I.

Geometaphors underlie the definition of *MGISQL* and are used to specify all the elements featuring in a GIS domain, including, e.g, geographic data, and either topological, or directional or metric relations. The main feature of the *MGISQL* environment is the use of a *Sensitive Board*, which is an interactive drawing area, where visual queries are formulated. Its sensitivity is related to the capability of translating a visual query (expressed in terms of geometaphors) into a corresponding GIS query by taking into account the context in which the query is posed. Besides that, the Sensitive Board can be assigned one out of four different *sensitivity levels*, level 0 corresponding to the absence of spatial relations in the query formulated, and the others corresponding to the specification of topological, directional and metric relations, respectively. The interaction of *MGISQL* with the underlying GIS ends up with the creation of appropriate geometaphors associated with the query results, which the user may decide to retain and exploit in the formulation of compound queries.

In *MGISQL* the manipulation and retrieval of geographic data are performed by two kinds of queries, geographic query and combined query, respectively. A *geographic* query is an extended kind of spatial query which involves spatial operators and *thematic functions* as a means to derive new information, while a *combined* query retrieves semantically related data from separate alphanumeric and spatial databases.

Geometaphor		
Drawing		
Icon	*physical representation*	
	meaning	Church

Table I. The components of a geometaphor for the geographic data Church.

As sketched in Figure 5, an *MGISQL* query is handled over to the underlying GIS, which can directly process it. The geometaphor of the query solution is finally visualized on the Sensitive Board. The figure also shows the Query Descriptor, which can be used to visualize a textual description of the *MGISQL* query, at any time during its construction.

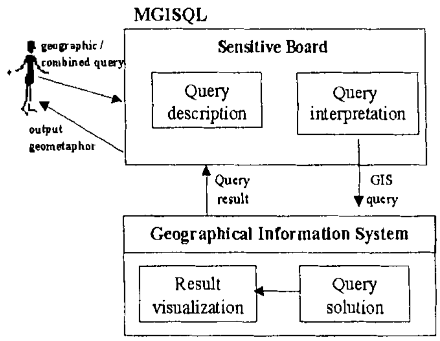


Figure 5. The interaction with the underlying GIS.

In order to retrieve geographic data from a GIS by taking into account their spatial features, geographic queries are formulated explotinig *spatial operators* and *thematic functions*. For the sake of brevity, in the following two subsections we recall these notions by means of examples, while referring to [12] for their formal definitions.

Spatial Operators in MGISQL. In [12] three categories of spatial operators have been identified, namely the topological, the directional and the metric ones that can be applied to geometaphors. In the following we recall their use by means of three examples.

Let us first consider the geometaphors

and


, which refer to the data Road and Archaeological Area, respectively. The topological operator adjacent(


,


) is based on the adjacent topological relation between a line and a region, corresponding to the geometric components of Road and Archaeological area, respectively. In fact, the resulting geometaphor


refers to roads adjacent to archaeological areas. Similarly, the directional operators are based on directional relations. As an example, the north operator applied to the geometaphors

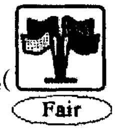

(Parking area) and


(Fair), denoted by north(


,


), returns the geometaphor

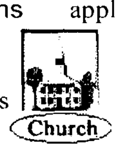

which is referred to parking areas located to the north of fair areas.

The last example is concerned with metric operators. The underlying relations are usually characterized by some metric constraints that also affect the definition of the corresponding operator. As an example, the max_distance operator, satisfying the condition "<1mile": max_distance$_{<1 \text{ mile}}$(


,


) returns the geometaphor


, which refers to the set of parking areas which are far from fair areas no more than one mile.

Thematic Functions. Besides spatial operators, users can formulate a geographic query through the application of thematic functions. Thematic functions can be used to create new geometaphors for a given theme starting from existing ones. The resulting set of geometaphors represents a real world situation associated with the original theme and is therefore called a *context*. As an example, let us consider a city map where the TOUR ITINERARY theme corresponds to the sightseeing tour which includes churches, monuments, parks and museums. The thematic function Jubilee_paths applied to the geometaphors


(Church) and


(Monuments) outputs a

context  ***Jubilaeum 2000*** (Jubilaeum 2000) containing the set of churches and monuments that belong to touristic itineraries established during the jubilee year, and a set of private chapels and monuments which have been opened to public access for this occasion. The latter correspond to new geometaphors since new geometric and alphanumeric attributes characterize them (e.g, areas opened to public access, as geometric attribute, and the period of free admission, as alphanumeric attribute).

THE *ViSaGIS* ENVIRONMENT

In the present section we show the effectiveness of the proposed visual environment in the management of cultural treasures, by describing the experimentation carried out with the *Visual Salerno GIS* (*ViSaGIS*) for promotion purposes. Thanks to the use of geometaphors and to the expressiveness of the *MGISQL* language, *ViSaGIS* users can intuitively manipulate both the spatial and the thematic components of the geographic data. Figure 6 shows the *ViSaGIS* environment where *MGISQL* runs. Its major components are the *Sensitive Board*, which is the interactive area where queries are formulated and the resulting geometaphors are displayed, and the *Geodictionary*, which contains the geometaphors on which queries may be posed.

The Sensitive Board

As discussed in Section 3, the Sensitive Board enables the application of the spatial operator on a set of geometaphors by simply analyzing the geometric representation of their drawings given the supplied parameters.

When formulating a query, the *ViSaGIS* user is allowed to choose one out of four *sensitivity levels* characterizing the Board.

The higher is the level, the more meaningful become the details about the kind of spatial operators involved. The query depicted in Figure 7 involving the

geometaphors 

(Theatre) and 

(Parking) has been associated level 1, which corresponds to topological relations. Therefore it is interpreted as 'retrieve the set of theatres adjacent to parking areas'. If the same visual arrangement was associated with level 0, it would mean that the user is only interested in the information content carried by the involved

geometaphors 

and 

. Similarly, if level 2 was selected, the meaning of the query would be

north_west(

, 

).

Finally, if level 3 was set, a pop-up menu would be displayed, from which the user might select the appropriate metric operator and possibly associate a condition with it.

The user may interact with the visual environment and verify the correctness of the query formulation while composing it. This can be done by clicking the Describe button, which invokes the Query Descriptor, the module that provides a textual description of the query the user is visually editing.

The Geodictionary

The Geodictionary (the area on the right of the interface) contains the geometaphors characterizing the ViSaGIS domain. These refer to museums, monuments, churches, theatres, parks, excavation sites and all the artistic and archaeological information related to the area of Salerno. As illustrated in Figure 7, the Geodictionary only contains the iconic representation of each geometaphor, while its drawing part (i.e., the representation of its topology) is visualized only when the icon is put on the Sensitive Board to take part in the query composition.

As discussed in Section 3.2, thematic functions can be used to derive new contexts and add geometaphors to the Geodictionary. Users can identify the set of geographic data on which the spatial relations must be verified by selecting the context of interest corresponding to the query domain. Such a context is visualized as a pattern which is used to fill the background of the Sensitive Board.

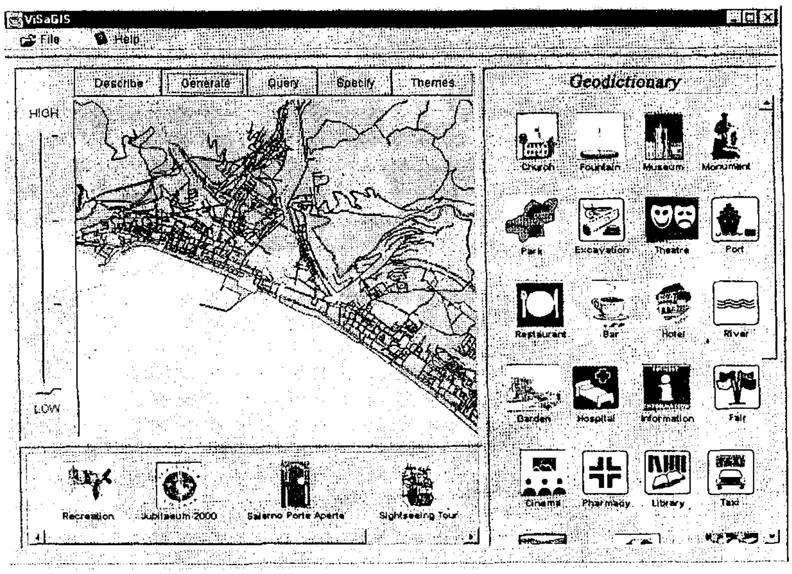


Figure 6. The *ViSaGIS* environment.

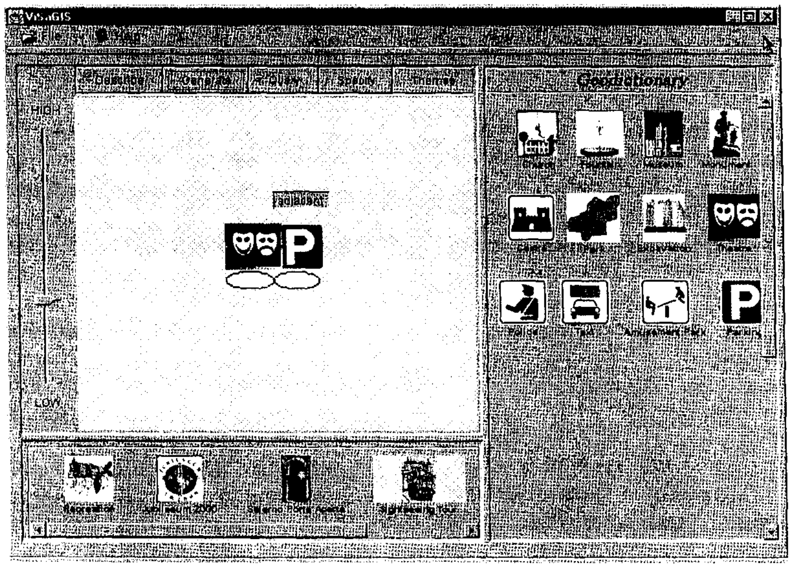


Figure 7. The formulation of a visual query.

Figure 8 shows the application of the thematic function Jubilee_Paths in order

to derive the context 

. The geometaphors 

, 

, 

and 

appearing in the Geodictionary represent the results of the thematic function and the map on the Sensitive Board displays the sites where the corresponding geographic data are located.

Visual query formulation

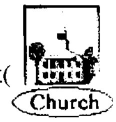
As previously described, a ViSaGIS user can formulate queries through the spatial arrangement of spatial operators and geometaphors. During the query formulation, the user drags the involved geometaphors from the Geodictionary, spatially arranges them on the Sensitive Board, and specifies the kind of spatial operator, by selecting the corresponding sensitivity level of the Board. The dominant element is dropped first, and the corresponding topology is also visualized. Then the second element is dropped, with its topology displayed. When the user presses the Generate button, the output geometaphor is built, with the corresponding topology as its drawing part.

The icon is automatically built by bringing the dominant element to the front. Finally, the Sensitive Board displays sites satisfying the query and, on demand, the *ViSaGIS* user can visualize more details related to the required geographic data, such as images and videos.

The construction of geometric features of the output geometaphor is performed by considering both the order in which the involved geometaphors are specified and the kind of spatial operator applied (i.e., topological, directional or metric). As an example, the output geometaphor of the query depicted in Figure 7 is 

where the associated topology is derived from the dominant operand 

. Then, Figure 9 shows the map of Salerno where the two occurrences associated with output geometaphors are located, and visualises their corresponding images.

More sophisticated queries can also be posed, which combine spatial and alphanumeric queries. *Combined queries* retrieve semantically related data from separate alphanumeric and spatial databases. The information about semantically related data is present in the GIS in terms of cross-referenced attributes. The involved spatial data must be semantically related to some alphanumeric data appearing in the FROM clause of the SQL statement, which expresses the alphanumeric component of the query. As an example, the *ViSaGIS* query depicted in Figure 10 is a combination of a spatial query Q_S = adjacent(

, 

), which refers to the churches adjacent to Mercatello park, and of the SQL statement Q_A:

SELECT name, address
FROM Church, Park
WHERE (Service_h > "17.00"
AND Service_h < "18.00")
AND Church.zonecode = Park.zonecode
AND Park.name = "Mercatello"

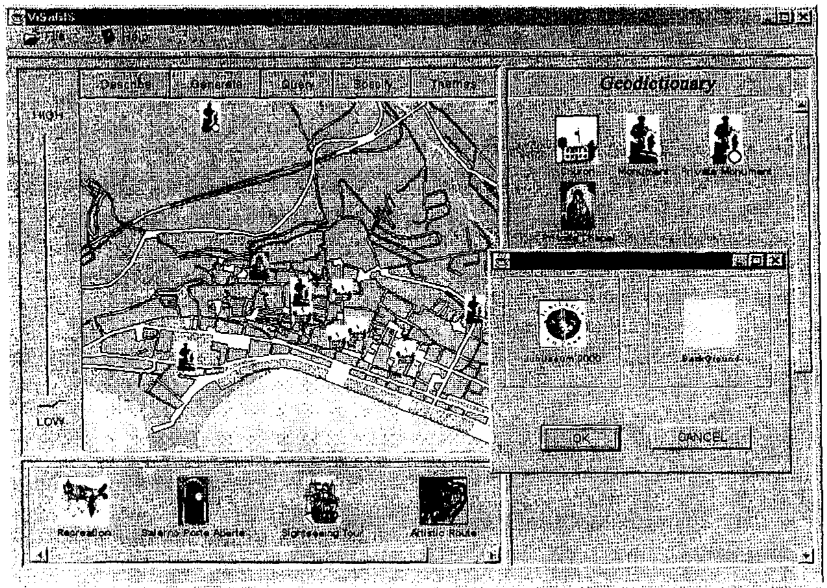


Figure 8. The application of a thematic function

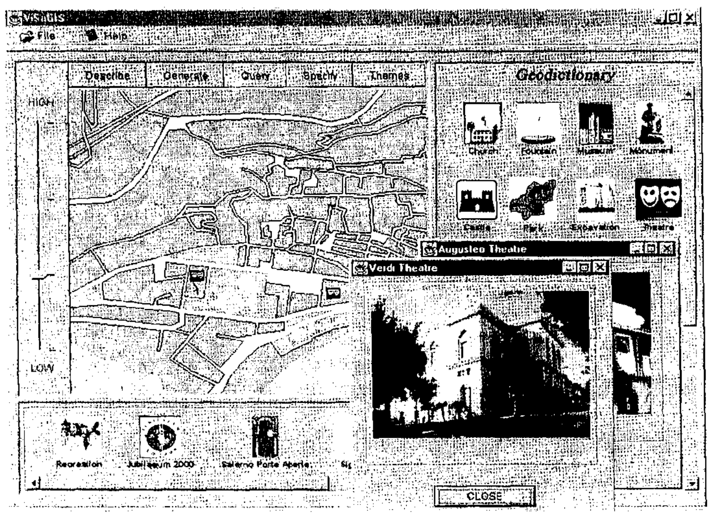


Figure 9. The output corresponding to the *ViSaGIS* query of Figure 7.

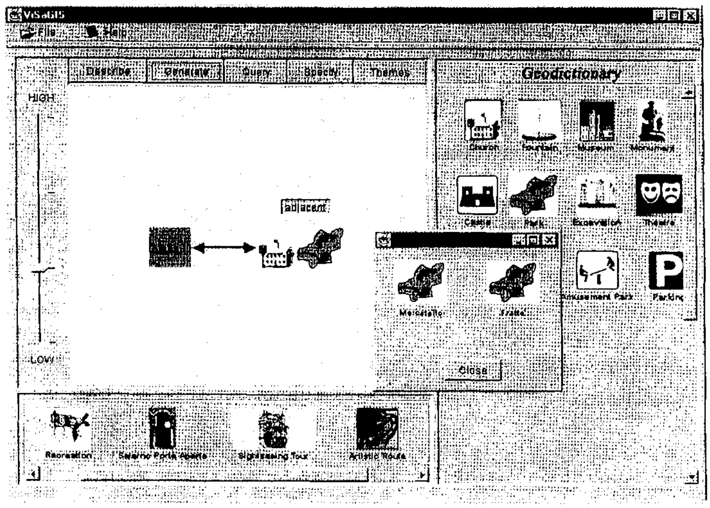


Figure 10. The formulation of a combined query.

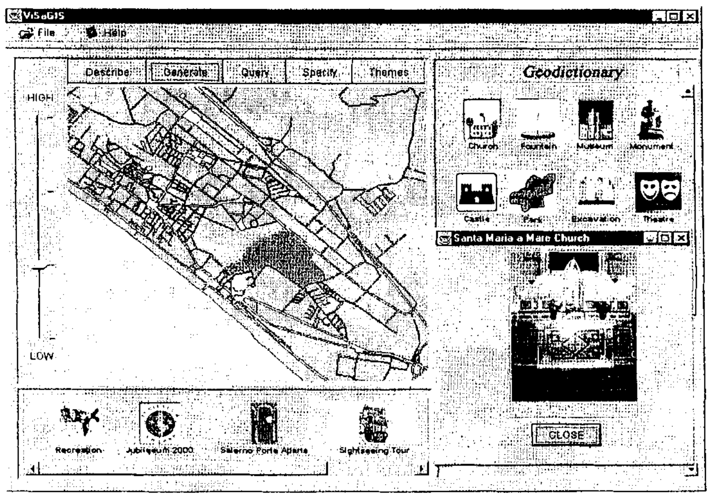


Figure 11. The visualization of the query result

which returns the set of churches which are located on the same zone as Mercatello park is, and where a ceremony is fixed between 17.00 and 18.00 o'clock. The link operator (represented by a double-headed arrow) is used to relate both the spatial and the alphanumeric components and it ensures that the two components of the query result are not only semantically related but also refer to the same geographic data.

In the figure, the background pattern of the Sensitive Board corresponds to the context  (Sightseeing tour),

Sightseeing tour

while the sensitivity level has been set to 1, which refers to topological operators. Thus, the result of the query interpretation is the set of geographic data referring to churches which are located near Mercatello park and where a ceremony is fixed between 17.00 and 18.00 o'clock.

Figure 11 shows the area corresponding to the involved park, the location of the church satisfying the query depicted in Figure 10, and the corresponding image.

FINAL REMARKS

The goal of our proposal has been to encourage the exploitation of GIS technology in the organization and manipulation of historical and artistic information. The *ViSaGIS* experimental system has been developed within the *MGISQL* visual environment in order to provide non- expert GIS users with full visual support to the manipulation of geographic data carrying artistic and archaeological information about the area around the city of Salerno. In the discussion carried out throughout the paper, we have put special focus on the thematic aspects of geographic data, which are traditionally expressed in terms of textual descriptions. The concept of geometaphor has been presented as a means to associate the visual representation of the spatial properties with an iconic component, able to resemble the described thematism. Let us finally stress that a remarkable feature of the proposed visual environment is the use of the Sensitive Board. This active area, where visual queries are constructed, has the capability to enable the query interpretation, further enhancing the users' interaction with the underlying GIS database.

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