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A New Language for Geographic Information Systems Querying

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Abstract: This study proposed a new language which offers the possibility to query Geographic Information Systems (GIS) with visual queries. Following the progress of the society and the development of technology, there is much more demand for geographic information. But, most of the Geographic Information Systems (GIS) available now are geared toward professionals. They do not have a friendly query interface and only well-trained persons can get information from them. Ordinary people cannot benefit from GIS directly. So, it is valuable to construct an easy-to-use visual query system to retrieve geographic information. To address this problem, we have developed a new visual language. A query is formulated in this language by successive selections of icons and metaphors. A prototype running ENVIS has been realized, which allows users to query experimental data by following a SQL-like SELECT-FROM-WHERE scheme.

Key words: Query languages, geographic information, geographic databases, visual interfaces

INTRODUCTION

The formalization of a GIS querying language in the geographic information sciences is an important research topic since the last twenty years.

At present, two major problems are examined by the researchers in this field:

- A first category tries to answer the question: Which are the types of geographic queries generally specified by the users?

That results in establishing not only one coarse classification of the types of geographic processing as shown in Table 1 (Theriault, 1996), but also in analyzing the types of queries most frequently formulated by a category of given users.

Table 1: Types of processing with GIS

Processing	Uses	Examples of requests
Location	Located inventory	What is in this place?
Distribution	Analyze set of themes	Where is such phenomenon found?
Evolution	Temporal analysis	What has changed since?
Distribution	Spatial analysis	Which is the form, the structure or the functional organization of?
Modeling	Simulation of the processes	What would it occur if?
Optimization	Decision-making support	Which is the best way?

- A second category is given the objective to answer the question: Which query mode (and interaction) to recommend for a geographic type of given query?

This question is analyzed in the objective of making sure that the query mode proposed is the most natural for the users. It must take into account the preferences of these users and propose an interface adapted to their profiles.

In this second category of research, several works were carried out these last years, based on various approaches that are rapidly examined.

The first approach directly uses the principles of algebra and geometry. Study of Tomlin (1983, 1990) based on the cartographic algebra are most known.

One second approach is based on the use of formal languages often issued from standard SQL, with Egenhofer (1991) studies on the extensions of the SQL, PSQL (Roussopoulos *et al*., 1988), SQL3 (Snodgrass, 1995; Snodgrass *et al*., 1998) and many other alternatives. In this approach, one extracts information from the system by using a built query. This approach is by nature not adapted to naive users (not mastering data-processing tools) because it requires often hard training.

- A third approach still in research in the GIS community is where the access to geographic

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information is done by the exclusive use of the natural language? This approach turns around the natural language in the context of the spatial expression, strongly supported by research in cognition, language and data processing

However, the suitable phenomena for the natural language (paraphrase, inference, etc.) are very difficult to master from the point of view of understanding.

This approach currently turns against the problems arising generally from the processing having for objective the understanding of the natural language. Indeed, the formulation of the queries can prove to be long (a drawing is worth thousand words). Textual queries are still difficult to interpret though recent solutions are proposed by Ploux and Ji (2003).

- The fourth approach is described as figurative. The interfaces based on this approach often offer some visual means (icons, diagram and drawing) in order to express required information

A first family of this approach offers a relative freedom to the user to draw his spatial configurations. Spatial-Query-By-sketch (Egenhofer, 1996, 1997) and the language Sketch! (Meyer, 1993) are examples of this approach

The second family of this approach represented by Calcinelli and Mainguenaud (1994) and LVIS (Bonhomme *et al*., 2004), offers a set of icons which represent the geographic features that one can combine to build a query.

The languages we have just presented show considerable improvement in the field of visual spatial query languages. However, they also have currently some limitations:

- The language is not associated to a visual representation of the database schema: only textual representation (menus) of some concepts (e.g., object types and attributes) is usually provided. So, database schema and queries are not represented with the same paradigm and a part of the semantics of the database schema (IS-A relationship, for example) is not taken into account by the end user
- Non-uniform handling of spatial and non-spatial objects: even if the objects must be visualized in separated windows to avoid any ambiguity, they must be manipulated by means of the same language in order to avoid the tiredness of a cognitive overload
- The specification of classical operators (e.g., Boolean operators and quantifiers) is not well studied: it is sometimes difficult to express a disjunction (OR) and usually impossible to visually express a universal quantifier (ALL). We meet here the problem of visual specification of complex queries
- Certain spatial operators are not available: it is often the case, for example, of directional operators (e.g., North, left of) and topological operators in 3D
- Expressive power of the query language is unknown. Its study implies to formalize the language and to define some levels of completeness
- The temporal aspects of spatial objects are not considered. Depending on the type of time considered (Spaccapietra *et al*., 1998) it is sometimes necessary to take account of the fact that a spatial object (e.g., a river) can move, be modified or transform itself into an object of another type. Some graphical languages have been proposed by Calcinelli and Mainguenaud (1994) and Cardenas *et al*. (1993) but they all use too much graphical conventions to really be used by final users. We really believe that the best way is to define a visual language (i.e., using visual metaphors) associated to a conceptual model capturing the semantics of the spatio-temporal information. In this context, the paragraphs which follow in this article describe our solution for the GIS querying

Preliminaries: Before the presentation of our approach, we will start by giving a definition of the type of information which interests us within the framework of this study.

Many authors gave multiple definitions and descriptions of geographic information. The concept of geographic information adopted within the framework of this study, was defined by Congiu *et al*. (1995) as a cognitive process (acquisition, interpreting/reasoning, expression) guided by contexts and uses applying to observations carried out to entities located in a geographic space, in order to restrict possible interpretations of them (to confer a meaning).

This general standard lays before the concepts of observations, located entities and geographical space which it is necessary to specify or to define with precision geographic information.

Geographic space is a physical or geometric space in which it is possible to carry out observations (Turbout, 2002). These observations are related to geographic space and characterize the various components of this space: geographical features shown in Fig. 1.

In addition, each observed geographic feature can be described by: its geometrical shape (the form, the position), the topological relations which it maintains with other entities, its semantic attributes (textual, qualitative, quantitative information on a feature with the exception of the geometric and topological aspects).

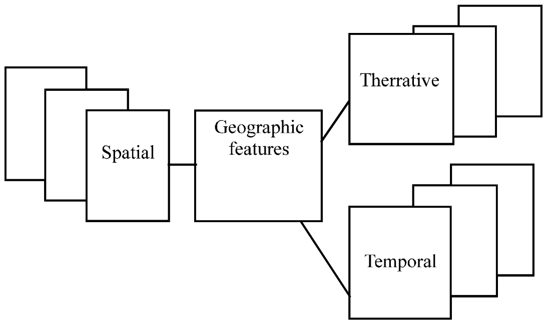


Fig. 1: Geographic data consist of geographic features and a set of observations related to certain reference systems

A new visual query language for GIS: Geographic information is visual information by essence, moreovervisual languages based on the metaphor of the blackboard using the combination of icons are friendly and simple of use; their query mode is simple and welladapted to the occasional users who are not experts in the domain. The figurative approach was recommended in our study to solve our problems of GIS querying. The following sections present our conceptual model as well as the various basic concepts of design which were used for the implementation of our prototype ENVIS.

Visual approach: A user who wants to query GIS data has already delimited his field of action i.e., he already builds his query in terms coming from his field of expertise.

In order to represent the reality as seen by a user, it is really a translation effort to formulate a query concerning his center of interests by means of the available vocabulary.

In ENVIS, the formulation of the query is based on successive selections of icons and metaphors. During this formulation the visual representation of the center of interest of the user is built gradually.

The icons represent the objects of the geographical database; the metaphors represent the types of objects and the relations necessary to the expression of the spatial and temporal constraints in the query.

CONCEPTUAL MODEL

First of all, let us specify what is understood by a spatial database. The objects of a spatial database have an object-ID, an identifier of theme (in general consisted in the theme of the object and its name, the spatial location, the temporal location and a set of attributes values (primarily, with alphanumeric values).

We suppose here that all objects have a spatial location determining their spatial type and their geometry (in the form of a sequence of points of space). We also consider the specific, linear and surfacic objects. The visual representation of these spatial types (linear and surfacic) is given such as the specific objects are compared to surfacic objects of null surfacic and thus, their visual representation is the same one as for that of the surfacic objects.

Lastly, let us note that some objects do not have a significant spatial location. The mobile objects, for example, are in perpetual movement. These objects are then compared to specific objects and their spatial location is related to their temporal location.

We also suppose that all the objects have a temporal location expressed in the form of an interval of time delimited by two dates according to a given temporal axis. One date is regarded as being an interval of null duration.

A type of object of the database will be represented visually by its theme type and its spatial type. In the same way an object is represented by its theme identifier and its spatial type.

The theme type is visualized by an icon. The theme identifier consists of the icon of the theme type and a text value which is a label of this icon.

The visual representation of the spatial type is then linked to a theme type (resp. theme identifier) to give the complete visual representation of an object type (resp. object).

The theme type is the logical name of a table or a layer of map of the database. The theme identifier indicates an object of the table or the map layer the name of which corresponds to the value of its theme type. Thus, in our database example, the theme types and thus the tables, are forest, river, town and roads.

A query contains objects or types of objects with one or more criteria. The objects or types of objects of the query constitute its operands; criteria are the operators applying to its operands.

The query formulated on a spatial database is qualified of a thematic query, spatial query, temporal or spatio-temporal query according to the contents of their criterion of selection. Thematic queries do not include any spatial or temporal criteria. Spatial (temporal) queries are defined with one or more spatial (temporal) criteria. Spatio-temporal queries involve at least one spatio-temporal criterion or a combination of spatial and temporal criteria.

A thematic query (resp. spatial, temporal, spatiotemporal) relate to the values of the theme attributes (resp. spatial location, temporal location, spatial location and temporal location) of the objects of this query.

Global architecture: Figure 2 shows the levels of languages integrated in our system: visual, pivot and target.

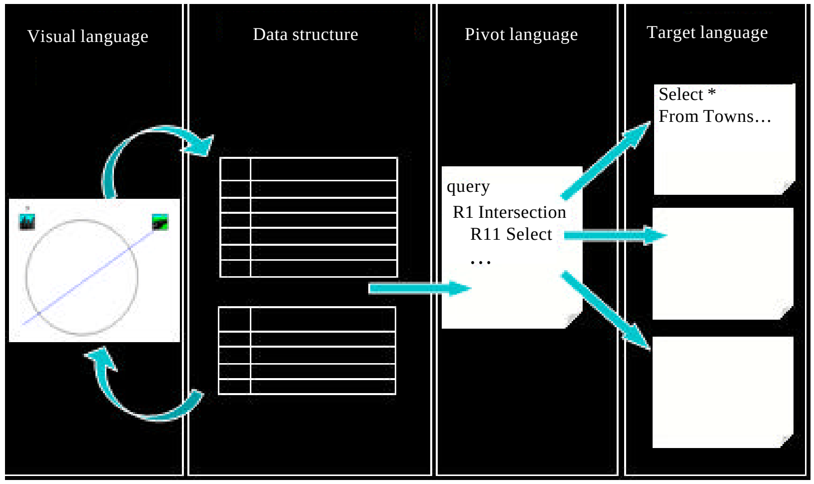


Fig. 2: Global architecture

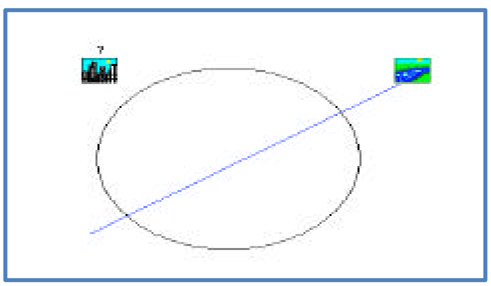


Fig. 3: Visual representation of a query

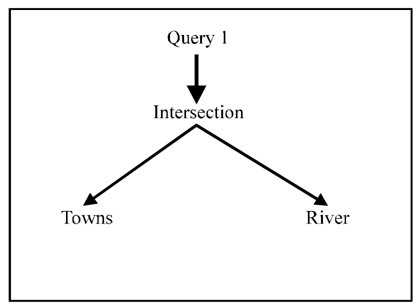


Fig. 4: Structural representation of a query

A textual expression is associated to a visual query. This expression is based on a pivot language. This pivot language is based on a lexical parser that aims to be compatible with the standardized Spatial-SQL for spatial operators and with TSQL2 for temporal operators. A query expressed in this pivot language is then translated in target language: GIS host language. We have chosen the marketed GIS MapInfo to perform tests on an example database.

The visual query shown in Fig. 3 is associated to a structural representation: binary tree as shown in Fig. 4.

Two translation modules have been implemented:

- Extraction of a textual representation from the structural representation of a given query
- Translation of the query from the pivot language to the target language

The prototype ENVIS: Figure 5 shows the principal interface of our prototype ENVIS.

A set of icons representing objects types stored in the database is available. Figure 6 demonstrates the appearance of some objects types.

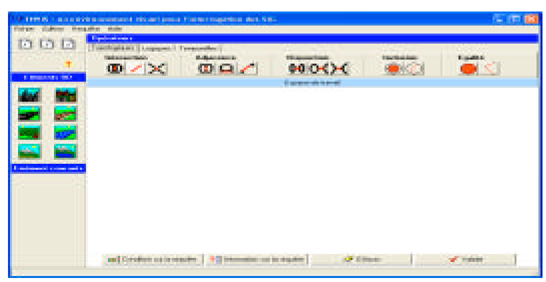


Fig. 5: ENVIS interface

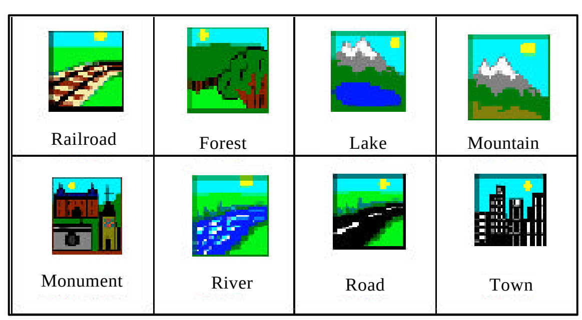


Fig. 6: Object types of the queried database

Operators like logical shown in Fig. 7, topological and temporal shown in Fig. 8 are also represented using icons.

Logical operator	Visual representation
OR	ou
AND	et
NOT	non

Fig. 7: Logical operators considered in ENVIS

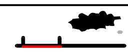
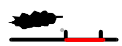
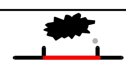
Temperal operator	Visual representation
After	
Before	
During	

Fig. 8: Temporal operators

RESULTS AND DISCUSSION

The ENVIS comprises an editor of visual query in the center of which a working space is reserved for the construction of a query starting from the selected visual elements step by step. The user first selects object types within the database and then applies an operator.

Three icon selections are sufficient to express a thematic, spatial or temporal query between two object types: two selections of object types and one for the application of a binary operator.

Figure 9 shows the visual formulation of the following spatial query: Which towns are intersected by road? This query is built by the application of a topological operator (intersect) between a linear object of type road and a polygonal object of type towns.

At the end of the formulation of the query this one can be stored for a later use, erased in the event of error or validated and then must be translated into the target language. Figure 10 shows the translation of the visual query shown in Fig. 9 into the target language.

The valid query can then be modified by successive refinements: the user may add new object types and apply new operators to the whole query or a sub-part of the current query. Complex queries can be formulated by following this principle. Figure 11 shows the visual formulation of an example of complex query with tree objects.

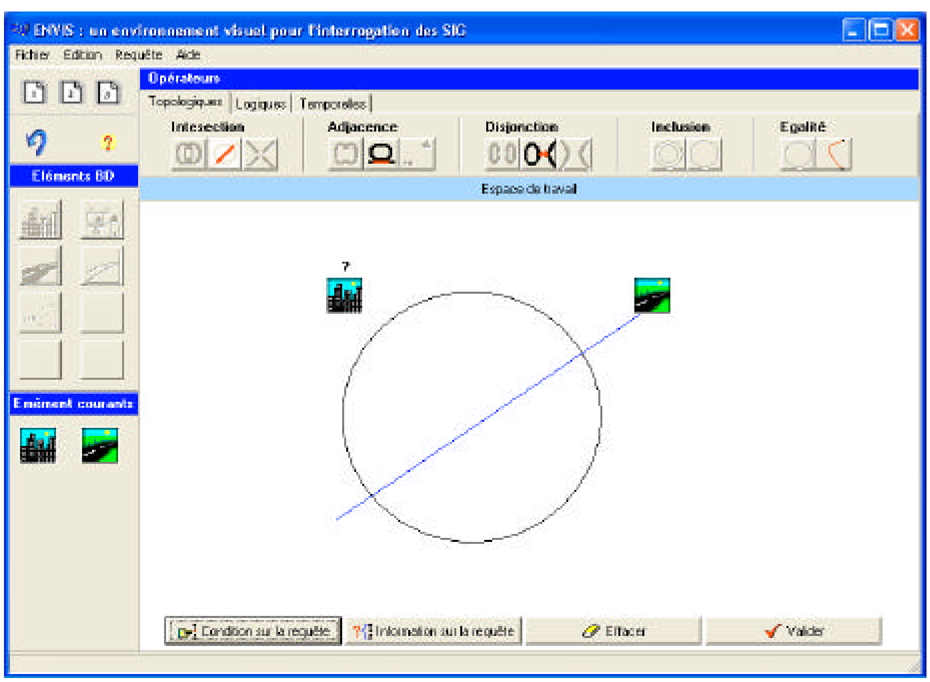


Fig. 9: Visual formulation of a spatial query

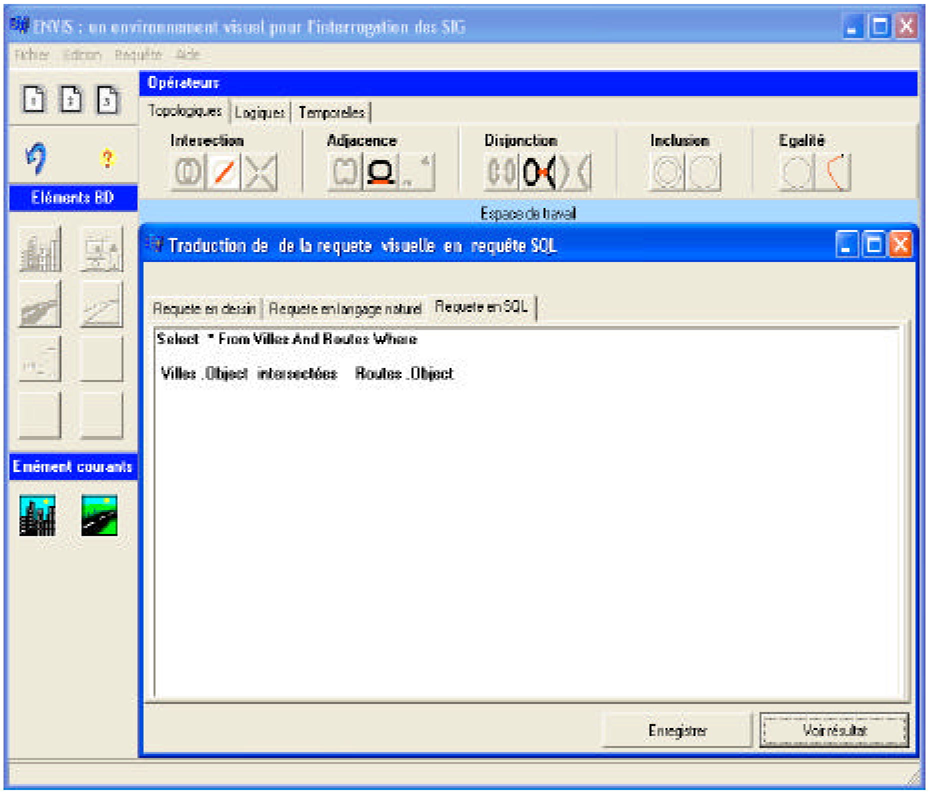


Fig. 10: Translation of the visual query in SQL language

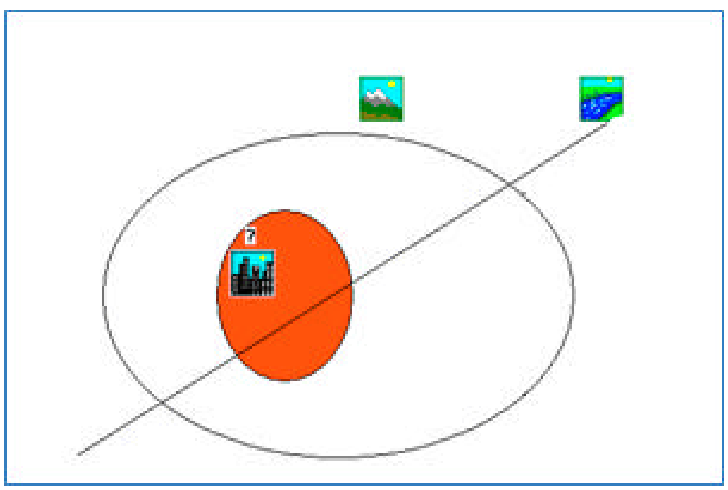


Fig. 11: Example of visual query with tree objects

Other conditions as specified in Fig. 12 can enrich the visual query such as Boolean expressions.

We have chosen the marketed GIS MapInfo to perform tests on an example database. Moreover, a set of cognitive tests have been done. Their major aims are to show that the icons of the language (especially spatial operators) are well recognized by end-users. Both persons working with GIS and persons non expert in geography or in computing have been tested. The first results show that icons of the language are well accepted by the two populations.

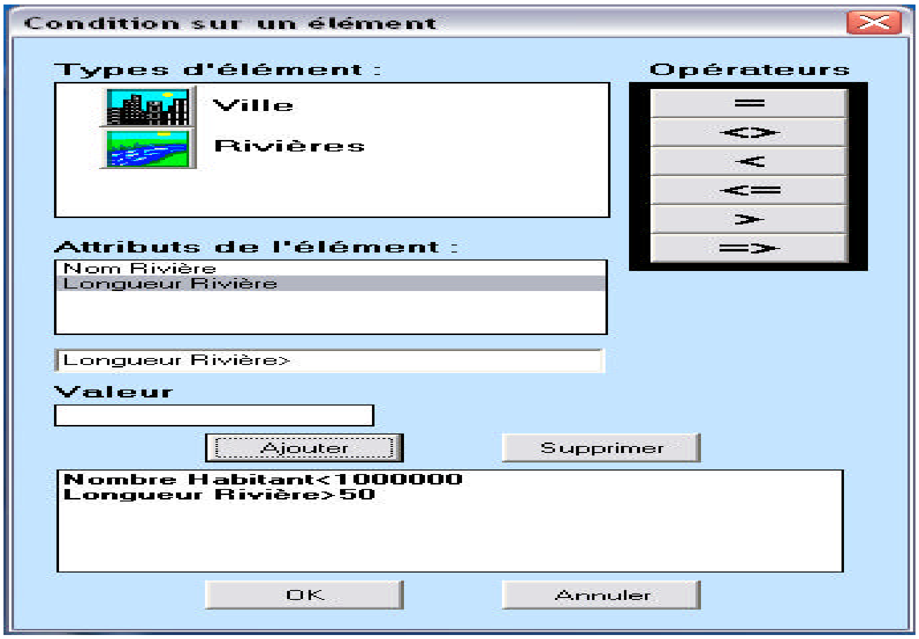


Fig. 12: Conditions form

CONCLUSIONS

The querying is one of the most important operations in the life of a GIS. It thus appears that a particular interest must be taken to the interfaces and the effectiveness of the means of querying offered to the GIS user.

Our prototype called ENVIS which was presented in the preceding sections was designed and produced in the aim to meet these problems of GIS querying.

The ENVIS uses the formulation of geographic query in a visual way. With this intention, we initially choose the adapted visual representation of data. We have then identified the various necessary steps for the visual expression of the query.

This querying mode offers a simple and easy means to the end-user who expresses his query with icons and metaphors. The visual representation seems to be a representation adapted to the user of the GIS and a very promising field to solve problems of GIS querying.

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