Querying Moving Objects in GeoPQL

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Introduction

In recent years, spatio-temporal databases are receiving considerable attention due to the extensive amount of applications dealing with objects that change their spatial characteristics over time. For example, applications for tracking vehicle (cars, trains, aircrafts or ships), environmental change monitoring or the analysis of group/individual movement behaviour require the storage and querying of spatial objects changing continuously over time (moving objects). To consider together spatial and temporal features of data is the first challenging requirement of spatio-temporal database and consequently it represents also the topic of considerable research activity.

Another important research topic concerns the development of friendly and simple query languages that allow to ask for temporal changes in spatial situations. Although traditional textual query languages have been proven to enable the user to express complex requests, the ease of use of such languages is very limited, particularly for non-expert users. Thereby, the visual-based querying paradigm has emerged as the most intuitive and natural one, trying to offer a good trade-off between expressiveness and intuitiveness. In particular, a large number of visual languages has been proposed to query spatial database, as spatial relationships are well suited to be represented through visual notations. Temporal changes of spatial relationships are more difficult to be visually expressed due to the immaterial nature of time. Therefore, the graphical representation of the temporal dimension is a challenge for visual spatio-temporal query languages.

The aim of this paper is to gather the two challenges described above by proposing an extension of the Geographical Pictorial Query language (GeoPQL) [Ferri et al. 2005] in order to support visual spatio-temporal queries. The main contribution is the representation of queries on moving objects in a three-dimensional space where the spatial dimension is described by a two-dimensional layer and the temporal dimension is the third dimension of this space and, therefore, the overlap of layers allows to represent the temporal changes of spatial situations. In this paper, after a brief discussion about existing research activities related to this work, we analyze the main characteristics of GeoPQL focusing on the spatio-temporal operators and their visual representation.

Related work

Although several proposals of visual languages for querying spatial databases exist in literature [Calcinelli et al., 1994] [Egenhofer, 1997] [Kaushik et al., 1998] [Aufaure-Portier et al., 1999] [Ferri et al. 2005], very few visual query languages have been proposed in the field of spatio-temporal databases [Erwig et al., 2000] [Bonhomme et al., 2000].

The visual spatio-temporal query language Query-by-Trace [Erwig et al., 2000] adopts the notion of *development* to represent the changing of moving objects. This notion is based on the evidence that temporal changes of spatial objects induce modifications of their mutual topological

relationships. Two types of primitives are defined, *moving point* and *evolving region*, denoting the motion and change in size for the spatial data types point and region (moving lines are not considered due to the lack of interesting applications). The query definition occurs through a sketch-based two-dimensional interface where the horizontal dimension contains the spatial information (a point is represented as a point and a region as an interval on the x-axis) and the vertical dimension describes time. Queries between two moving points or two evolving regions are possible as well as queries between a moving point and an evolving region. Having selected the appropriate primitives for the query, the mouse is traced on the canvas and the spatio-temporal predicate sequence is specified according to the mouse locations.

Another example of visual spatio-temporal query language has been proposed by Bonhomme et al. [2000]. It is an extension of the LVIS language [Aufaure-Portier et al., 1999] that includes also spatio-temporal operators (creation, split, merge, growth, diminution and destruction) that are represented using the balloon visual metaphor. Queries are expressed according to a query-by-example philosophy using icons representing object types (point, line and polygon) and operators.

Our approach, like Query-by-Trace, follows the sketch-based querying paradigm rather than the iconic one, as icons may not convey the expected meaning to users and be therefore even less effective than sketches. However, in our language the visualization of queries occurs in a three-dimensional space, rather than two-dimensional, and through the use of layers, whose overlap represents temporal changes of spatial relationships.

Spatio-temporal operators in GeoPQL

The Geographical Pictorial Query Language (GeoPQL, [Ferri et al. 2005]) allows the user to draw pictorial geographical queries and to obtain the objects, selected in the geographical database, which are the result of the query target. To achieve that, this language is based on various concepts that represent also the peculiarities of the language. First of all, GeoPQL allows to specify queries using Symbolic Graphical Objects (SGOs) consisting of the three classic types of shapes: point, polyline and polygon. In literature SGOs are usually referred to as icons, symbols, feature, etc. A formal description of this data structure is given in [Ferri et al. 2005]. Secondly, the current version of GeoPQL algebra consists of twelve operators, among which seven topological operators (Geo-disjunction, Geo-touching, Geo-inclusion, Geo-crossing, Geo-pass-through, Geo-overlapping and Geo-equality), four logical operators (Geo-union, Geo-difference, Geo-alias, Geo-any), and one metric operator (Geo-distance). Another peculiarity is that GeoPQL interfaces with ESRI's GIS ArcView®. The geographical query drawn by the user is translated in an eXtended SQL language, called XSQL. The textual query is continuously updated during the drawing phase, and it follows modifications, deletions and shifting of the pictorial query. At the end of the drawing phase the XSQL query is translated into ArcView® and executed on ArcMap® (the geographical database of ArcView®). The user thus obtains a layer on which the geographical objects that satisfy the query are stored and visualized.

Starting from these current peculiarities of GeoPQL, we have modified the SGO definition and introduced seven temporal operators (T-before, T-meets, T-overlap, T-starts, T-during, T-finishes and T-equals) and seven spatio-temporal operators (Geo-growing, Geo-shrinking, Geo-translation,

Geo-merging, Geo-splitting, Geo-appearing and Geo-disappearing) of objects in order to allow temporal and spatio-temporal queries. Consequently, in our spatio-temporal model we have introduced an extended definition of SGO to represent moving objects, which is given below.

SGO Definition. An SGO is a 6-tuple $\psi = <id, geometric\ type, time\ ref, objclass, \Sigma, \Lambda>$ where:
  - *id* is the SGO identifier, assigned by the system to uniquely identify each object in a query;
  - *geometric type* can be a point, polyline or polygon;
  - *time ref* is a time interval $[t_i, t_j]$ that indicates the period in which the SGO is valid;
  - *objclass* is the geographic concept name belonging to the database schema and iconized by ψ, identifying a geographic class (set of instances) of the database;
  - Σ represents the set of typed attributes of the objclass of the SGO to which the user can assign a set of values;
  - Λ is an ordered set of pairs of coordinates which defines the spatial extent and position of the SGO with respect to the coordinate reference system of the working area.

Due to the lack of space, we omit the definitions of temporal and spatio-temporal operators, as we would like to focus on the visual representation of spatio-temporal operators and queries.

In our approach we use a sketch-based interface that allows an intuitive specification of spatio-temporal situations. In particular, the interface permits to define different temporal layers. Each layer $l_{\psi_i}^{T_j}$ represents the spatial situation of the SGO ψ_i during the time interval (*time ref*) T_j of ψ_i. For instance, suppose the user wants to know all *Provinces* in Italy that have been split in two different provinces. He/she selects from the menu *Layer* the option *New* to initialise a new temporal layer of the query. In this layer the user can draw the initial spatial configuration of the SGO Province and specify its attribute as shown in Figure 1.a.
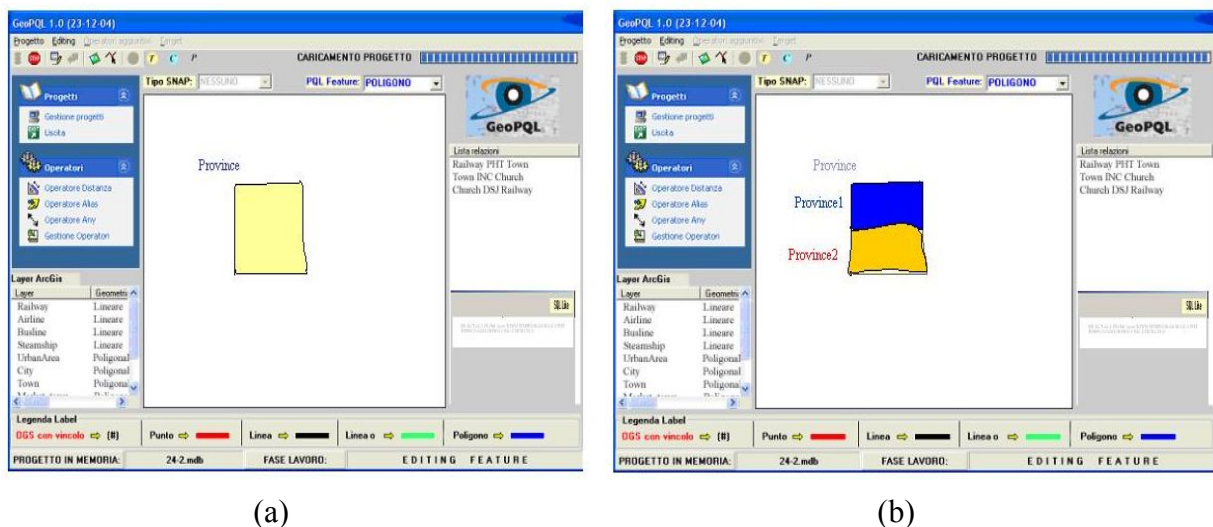

(a)   (b)

Figure1: Example of temporal layers specification

Once the first temporal layer has been specified, it is shown in the background of the editor. Depending on the second temporal layer specification, the kind of spatio-temporal operator is determined. As the user is interested in the splitting operator, he/she opens a new temporal layer and draws two Provinces, just overlapped to the Province drawn in the previous layer in the background (see Figure 1.b).

Therefore, as described in the query example above, the query specification occurs in two or more consecutive phases. In each phase *i* the user has to define the *i*th temporal layer (starting from the initial one till the last one) by drawing the spatial configuration of SGOs, involved in the query during the *i*th time interval.

At the end of the drawing phase, the system shows the visual representation of the spatio-temporal query in a three-dimensional space, where the x and y axes are used for visualizing the spatial configuration and the z axis is used for the time. For instance, the visualization of the spatio-temporal query in Figure 1, is shown in Figure 2. Note that the first layer (defined at time t1) is the temporal layer represented in Figure 1.a, while the layer defined at time t2 is the temporal layer represented in Figure 1.b.
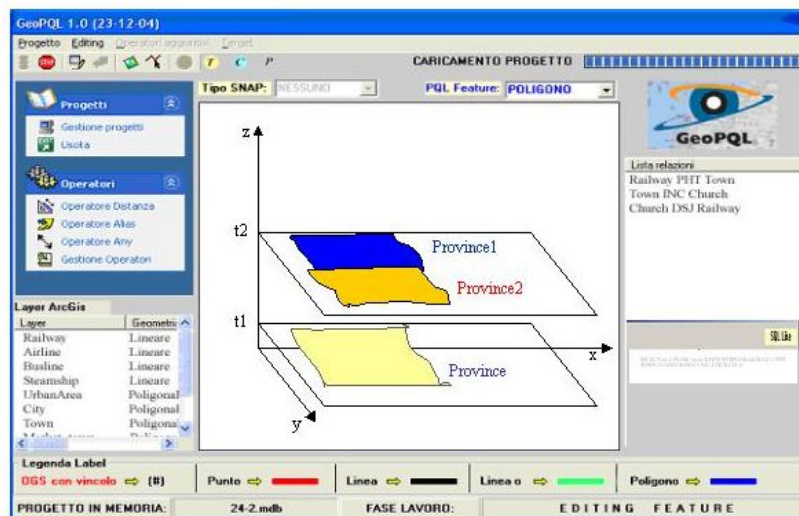

Figure 2: An example of visual representation of a spatio-temporal query

Conclusion

In this paper we proposed an extension of GeoPQL in order to express spatio-temporal queries. Our approach is based on the concept of temporal layer that allows to specify the spatial configuration of moving objects in a time interval. Moreover, the overlap of layers allows to represent the changes of spatial configurations. An example of query formulation allowed us to clarify our approach.

References

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