Syntactical and Semantical Correctness of Pictorial Queries for GIS

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### INTRODUCTION

One of the main topics in geographical information systems (GIS) research concerns the definition of high level visual query languages (Chrisman, 2002; Laurini & Thompson, 1992). This arises from the need to provide the user with a visual interactive tool for data manipulation and retrieval that is independent of the data’s physical organization. The use of standard query languages for spatial data handling (Rigaux, Scholl, & Voisard, 2001; Shekhar et al. 1999) has been hindered by the lack of appropriate language support. In fact, in visual query languages for GIS, a query can lead to multiple interpretations (Favetta & Aufaure-Portier, 2000).

For example, suppose the user wishes to formulate the following query: "Find all the regions that are _passed through_ by a river and _overlap_ a forest." In this query, the user does not express interest in the relationship between the river and the forest. However, when he or she draws a shape representing a region, and another shape representing a river, he or she cannot avoid representing a spatial relationship between them, and so every representation considering a specific relationship between the two features can be considered a valid representation of the query. Different visual queries can thus represent the previous query in natural language. In Figure 1.a, the river passes through the forest; in Figure 1.b, the river touches the forest; and in Figure 1.c, the forest and the river are “disjointed.”

Thus, the three representations should be interpreted as three different queries and, moreover, each query has a different meaning from the original query in natural language. Owing to semantical ambiguity problems, some configuration could be semantically invalid. For example, a lake cannot include a region. However, a visual query language with clear syntax and semantics can a priori overcome many cases of the ambiguities, minimizing multiple interpretations of a query for both the system and the user. This article discusses the syntactic and semantic correctness of spatial configurations in the context of nonprocedural geographic pictorial query languages. Thus, this article considers possible ambiguities related to visual representations of a query, and it does not consider ambiguities related to interactions between system and user.

### BACKGROUND

Various proposals of visual query languages for geographical data have recently been made. It is possible to classify these different languages into two main approaches.

In the first approach, the user draws his or her query freehand, directly on the screen, using the blackboard metaphor. Examples of this are _Sketch_ (Meyer, 1993) and _Spatial-Query-by-Sketch_ (Blaser & Egenhofer, 2000; Egenhofer, 1997). With this approach, the parser considers both the exact solution of the query and other approximate solutions obtained by removing or relaxing some constraints.

In the second approach, the user is free to draw iconic symbols on the screen, to express an object or an operator. Important examples of this approach are the

![Figure 1. Three visual queries representing the same query expressed in natural language](image-url)
Cigales language (Calcinelli & Mainguenaud, 1994; Mainguenaud & Portier, 1990) and the Lvis language (Aufaures-Portier, 1995; Aufaures-Portier & Bonhomme, 1999). In particular, Cigales is based on the idea of expressing a query by drawing the pattern corresponding to the result the user desires. The graphical forms and icons that conceptualize the operators are predefined.

Lvis is an extension of Cigales. The most relevant difference consists of the definition of new operators, because both spatial and temporal properties of the objects forming the query are considered. For this language, too, the main limitation is that there are different interpretations of the same query, that is, with the same visual representation the system is not able to give a unique interpretation. Ambiguity is increased with an increasing number of query objects.

Favetta and Aufaure-Portier (2000) confronted this problem and proposed a taxonomy based on user actions and system materialization (i.e., the different images the system can materialize), distinguishing ambiguities in visual query languages for GIS and ways to resolve them. They also proposed a model to solve a particular case of ambiguity. The proposed system, an enlargement of Lvis, established a dialogue with the user. Whenever an ambiguity occurred, it showed all the available configurations and requested a choice. The authors concluded that the strategy for avoiding ambiguities in most visual geographic query languages was to define not fully visual, but hybrid languages, including a textual part, and to offer a grammar with low expressive power.

The geographical pictorial query language (GeoPQL; Ferri & Rafanelli, 2004) is an evolution of the pictorial query language (PQL; Ferri, Massari, & Rafanelli, 1999), which resolved some previous limitations on ambiguities. It is possible to specify queries using symbolic graphical objects (SGOs) that have the appearance of the three classic shapes: point, polyline, and polygon. It is possible to assign to each SGO a semantic linked to the different kinds of information (i.e., layer) in the geographical database and impose constraints on both the SGO’s attributes and its spatial position. In addition, GeoPQL uses a limited set of graphical symbols to represent some operators that do not have a representation expressing the involved relations. Consequently, a generic pictorial sentence is represented by a set of symbolic graphical objects, a set of possible properties of each SGO, a set of possible symbolic operators, and the target of the query.

The GeoPQL algebra consists of two geometric operators: geo-union (Uni) and geo-difference (Dif); nine topological operators: geo-disjunction (DsJ), geo-touching (Tch), geo-inclusion (Inc), geo-crossing (Crs), geo-pass-through (Pth), geo-overlapping (Ovl), geo-equality (Eql), geo-alias (Als) and geo-any (Any); and one metric operator: geo-distance (Dst).

The symbols used for the symbolic operators are $\rightarrow$ for the geo-distance operator and $\leftarrow$ “relation name” $\rightarrow$ for the geo-any and geo-alias operators, (where “relation name” is any or alias).

Geo-any allows elimination of undesired constraints and, if a geo-any relationship is defined between a pair of SGOs, this means that no constraint exists between them. In contrast, geo-alias allows representation of more than one relationship (in OR) between a pair of SGOs. In fact, a graphical representation does not allow, for example, a pair of polygons that are both disjoined and overlapped.

One important issue is the definition of a sound method for analysis of syntactic and semantic correctness, of queries that may lead to multiple system and user interpretations. Thus, we illustrate an approach able to determine the exact syntactic and semantic interpretations of geographic configurations involved in queries expressed by a pictorial query language.

A visual query language with clear syntax and semantics can prevent a priori many ambiguities, minimizing multiple interpretations. The goal of this article is to present the configurations between geographical objects that can be considered syntactically correct in a geographical context, identify the set of GeoPQL operators referred to each configuration, and give each configuration a nonambiguous semantic.

**SYNTACTIC CORRECTNESS OF PICTORIAL CONFIGURATIONS**

In this section, a generic SGO pair, part of the set of all query SGOs, is considered. The set of operators syntactically admissible for this pair is defined, starting from possible spatial configurations (see Figure 2; Shekhar & Chawla, 2002). Thus the system considers for each configuration drawn by the user only the syntactically correct predicates, ensuring the syntactical correctness of the pictorial query. The proposed operators represent the constraints on the spatial properties of the objects (or classes) of the database that the user must specify in his or her query in order to find the geographic objects of interest.

Each possible spatial configuration is given a code of three alphabetic characters followed by a number. The first two characters indicate the type of SGO, the third indicates the type of spatial configuration, and the number distinguishes the configuration. In this manner, the first configuration between two polygons in Figure 2 is referred to as “aaA1,” the last as “aaE1.”
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