Spatial Alphanumerical Attributes for Graphical Treatings

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Abstract

This article introduces a general way to bring alphanumerical attributes into a graphical system to manage treatings. This semantics supply is done by a spatial operator closure using two spatial concepts: Topology and Granularity. Two graphical operator improvements are proposed, derived from spatial operators.

Keywords: *Spatial Closure, Graphical Coherency, Declarative Property*

1. Introduction

Multi-media information systems are largely used today in applications. These systems manipulate data as two parts: classical database (i.e., alphanumerical data), and structured or few structured data. When the data represent a spatial phenomenum, the multi-media system is called Geographical Information System (GIS), or Image Database System. In this article we present a way to improve integration between spatial and image systems.

A GIS is generally built from a conventional database (ad hoc. or relational), where a special attribute is used as an identifier for a spatial system (loosely-coupled architecture). The spatial system is able to manage data from several formats, in a range going from raster to vector. In the general case, [9] and [5] have proposed a way to bring some semantics into a spatial representation. The base observation is that spatial operators are not closed within a GIS. For instance let us answer the following requests:

- R1: "Display cities having more than 500,000 inhabitants".
- R2: "What are the common parts between the city "*My_City*" and the forest "*My_Forest*" ?"

For the first request R1, a GIS will return all cities from the alphanumerical tables, and then for each visual identifier of the resulting tuples, it will order the spatial system to display the elements. For the second request R2, a GIS will only return the spatial intersection, but nothing concerning the alphanumerical properties of this spatial intersection. The intersection operator has not been yet defined for alphanumerical part of data. If we consider the multi-media data composed by two parts: alphanumerical and spatial, then the Intersection operator is not closed when returning only spatial data.

Raster-to-Vector system are used as a reingeneering process. The aim of such a system is to transform data from a graphical level (images), to a spatial one (vector, GIS compatible). Treatings at the graphical level can be performed by a family of low-level operators. But the study case of OCR shows that image operators are complex, often domain dependent, and requires human corrections. The Image Analysis is a science that has been improved for many years, but is not still reliable enough. Among all main directions used to improve Raster-to-Vector systems [10], architecture improvement is emerging slowly. The coherency system involved, seems to be well adapted to GIS by sharing a part of information. This system tends to organize treatings in order to get at intermediate steps a graphical coherency, by a spatial coherency point of view.

In this article, we point out a way to improve graphical coherency by bringing some spatial semantics as the form of alphanumerical attributes. In part 2 we present a conceptual model of the Information System. In part 3 we present the main Raster-to-Vector coherency approaches, and then our improvement by defining a graphical relevant spatial attribute. We end this article in part 4 by a conclusion.

2. Information System Modelling

To get alphanumerical information (the semantics) on spatial representations, an operator closure is performed. This consists in deriving a conceptual operator into all sub-systems. Upper abstract level information (meta) are then required. As we are at a conceptual level, we use the formalism of the Abstract Data Types (ADT); we include such an information as a multi-media type named $Mtype$. We present first the ADT formalism and a structure named Multi-media OBject (MOB), then we present $Mtype$. We end this section by presenting the operator closure with a Toy DataBase example.

2.1. Abstract Data Type and Database Modelling

An ADT formalism description can be found in [1]. Let L be the basic rules to construct types. We assume that we are given a countable set of attribute names $a_1, ..., a_n$; that can be unambiguously recognized from any types in the system. Basic types are String, Integer, Boolean with their proper domains. Types are recursively defined by proper constructors: let $T = [a_1 : T_1, ..., a_n : T_n]$ be an association/aggregation type; let $T = \{a_1 : T_1\}$ be a set type, and let $T =< T_1, ..., T_n >$ an enumerated type. Operators are defined by an algebraïc signature, i.e., a cartesian product of domains for operands and results.

In the case of a GIS, spatial objects composed by alphanumerical and spatial parts are logically linked together by an attribute, and physically located in many sub-systems. Moreover, depending on the spatial format, few-structured data as bitmaps have to be handled too. We define a MOB [2] as a structure that contains both parts, and at two levels: as spatial as graphical. Let $AlphaType$ be a type for alphanumerical data (for instance a collection of attributes), SDT an abstract data type for spatial representations, GDT an abstract data type for graphical representation. A MOB is then defined by: $[\# : integer, a : AlphaType, b : SDT, c : AlphaType, d : GDT]$; $\#$ is an identifier, a and b deal with spatial data rather than c and d with graphical ones.
For instance with a Network document, a Concentrator is a special device devoted to collect lines from a global network to clients. In and Out are two alphanumerical Concentrator attributes that specify the number of Inlines and Outlines (in a general case, In is greater than Out). Model specifies a model type of the physical device. Then: $a = [Street : String, In : Integer, Out : Integer, Model : String]$. As examples for graphical attributes are the DotPerInch (DPI) or the number of colors. To improve this definition we use a p-graph to represent links between types inside a MOB. The labelling function will correspond to the Meta information. We suppose the graph is represented by a type named $Graph$, and the MOB graph is named G_{MOB}. Then: $MOB = [\# : integer, a : AlphaType, b : SDT, c : AlphaType, d : GDT, G_{MOB} : Graph]$.

To get a classical definition of a database, the base is composed by a graph of type $Graph$, for inter-MOB links. The name of this graph is G_{BASE}, nodes are MOB types and edges are links between MOBs. The semantics of links is similar to the one in the Entity-Relationship (ER) model [3]. The global structure is then composed by a graph of MOBs; and for each MOB there is a graph of types.

Meta information determination: MOB definition takes into account inter-types links with the G_{MOB} graph. The labelling function of this graph is an instanciation of a type $Mtype$ defined at an upper abstract level. This allows defining relations between types from MOB parts having different paradigms (e.g., alphanumerical, representation).
A conceptual analysis consists in defining statically $Mtype$ from those properties. [9] used two orthogonal concepts named Topology and Granularity for spatial data level:

- Topology: Validity for interior (in), limit (lim) or both (2) of the spatial representation,
- Granularity: Validity for a subset (ss) or the entire spatial representation ($inte$).

A $Mtype$ type is then built by an aggregation:
$Mtype = [Topology :< in, lim, 2 >, Granularity :< ss, inte >]$

2.2. Operator Closure

[9] and [5] have designed an operator closure process for GIS. This alphanumerical operator is obtained by selecting the relevant attributes for a given spatial operator. At the beginning there are conceptual operators such as adjacency, intersection, union, etc, defined by G_{BASE}. For each conceptual operator we define a table in the domain of $Mtype$, whose cell domain is binary: $< relevant, \neg relevant >$. This value concerns the validity of an attribute classified in this cell. In fact there is another step that must be handled: some operators such as inclusion or intersection can change the classification. So the real result must be taken after the classification has changed. As soon as alphanumerical attributes are statically classified, we can determine the resulting attributes for a conceptual operator by selecting relevant attributes.

To illustrate, we present an example of a network (schematic representation) analysis. We define a Toy DataBase with three MOBs: $\{$Line, Concentrator, EntryPoint$\}$. Figure 1 shows G_{BASE} of such a base. A visual example is given in figure 2 (the EntryPoints are on the right).

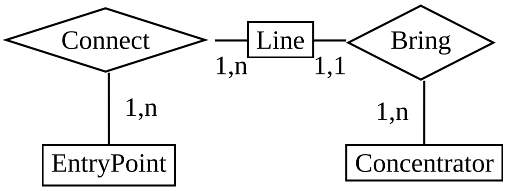

Figure 1. Network G_{BASE}

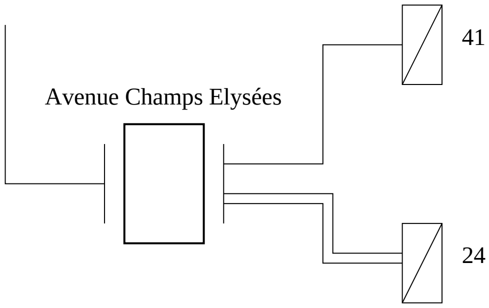

Figure 2. Network Example

Each MOB has a particular spatial alphanumerical attribute set, whose static classifications in $Mtype$ (T stands for Topology and G for Granularity) are given in table 1. Prefix letters correspond to the MOBs (C stands for Concentrator, L for Line, and E for EntryPoint).
As attribute definitions, LineMaterial is a Line attribute specifying the possible physical material for lines, from the type LineType=<Copper, Optical Fibre>. Armour is an EntryPoint attribute specifying the physical protection of the device; ArmourType=<Simple, Double>. At each possible value of ArmourType corresponds a graphical representation (Simple:blue, Double:red). PowerSupply is an EntryPoint attribute specifying the range voltage for the device; PowerSupplyType=<220,350>.

In a Network document, the main spatial operators are connexion operators (e.g., adjacency, borderline). A borderline operator ($\diamond$) in the domain of $Mtype$, is given in table 2, and an adjacency operator ($\lhd\rhd$) in table 3. On the lines are the values for Topology: T=$\{in, lim, 2\}$. On the columns are the values for Granularity: G=$\{ss, inte\}$. For instance, In or Out classified: $[T : lim, G : inte]$, would be relevant as the result for this borderline operator.

As examples, from these tables (without taking into account the identifiers), a borderline between Line and Concentrator (Line $\diamond$ Concentrator) is performed in table 4, by selecting every relevant attributes from Line and Concentrator, by using table 2. In the same way, an adjacency between Line and EntryPoint is performed in table 5.

Attribute	Domain	T	G
C.#	Integer	2	ss
C.Street	String	2	ss
C.In	Integer	lim	$inte$
C.Out	Integer	lim	$inte$
C.Model	String	in	ss
L.#	Integer	2	ss
L.FrameRate	Integer	2	ss
L.LineMaterial	LineType	in	ss
E.#	Integer	2	ss
E.StreetNumber	String	2	ss
E.Armour	ArmourType	lim	ss
E.PowerSupply	PowerSupplyType	in	$inte$

Table 1. Table of Attributes

$\diamond$	ss	inte
lim	relevant	relevant
in	¬ relevant	¬ relevant
2	relevant	relevant

Table 2. Table of Borderline Operator

$\lhd\rhd$	ss	inte
lim	relevant	¬ relevant
in	¬ relevant	¬ relevant
2	relevant	¬ relevant

Table 3. Table of Adjacency Operator

Attribute	T	G
FrameRate	2	ss
Street	2	ss
In	lim	$inte$
Out	lim	$inte$

Table 4. Table of (Line $\diamond$ Concentrator)

Attribute	T	G
FrameRate	2	ss
StreetNumber	2	ss
Armour	lim	ss

Table 5. Table of (Line $\lhd\rhd$ EntryPoint)

3. Semantic-Directed Graphical Coherency

An operator closure consists in selecting a subset of alphanumerical attributes, from data models depending on the semantics of a spatial operator. In this section we present a way to use this subset for coherency checking in the image sub-system.

3.1. Control Architectures

The transformation of data from a raster to a spatial level is a complex process. Treatings use coherency at each level. For instance, spatial coherency is defined from G_{BASE}, rather than graphical coherency uses structural or statistical definitions. Coherency involves control actions through all data levels. Three main control architectures exist: Top-Down, Bottom-Up, and Hybrid. Most of important systems have been developed with the hybrid approach; for instance Joseph [8], Den Hartog [7], Ramel [12], or Ogier [11]. Den Hartog's system uses relationships among objects (geometrical and graphical descriptions) as the main knowledge framework. Objects are not coherent when they do not share a permitted relationship. Ramel et al. build a structural representation from a draft, with a graph where nodes are primitives and edges topological relationships. Ogier defined two coherencies: objects are externally coherent with the neighbourhood, mainly with spatial relationships; and internally coherent in the sense of a graphical threshold with a particular subset of graphical elements.

As conclusion of these contributions, spatial coherency is already used and requires sometimes some alphanumerical attributes (i.e., the spatial semantics). But in order to generalize these approaches, it remains to define on what criteria have been chosen such attributes, and how they are used. We propose a way to formalize and generalize the use of spatial semantics with an hybrid approach, i.e., as a declarative form.

3.2. Semantic-directed Graphical Coherency

Semantics is viewed as alphanumerical attributes. Spatial alphanumerical attributes are not all relevant, depending on the spatial operator and the representation. First we define relevant attributes, and then we present an illustration with graphical treatings.

The spatial views [4] are a good way to present spatial data following thematics. GIS permit a large framework of applications, so have to cohabitate many external schema. To simplify the presentation, let us suppose we have a schematic static Network view in the system. The representation type is static in the sense that there are no scalable factors, no multi-level representations.

Graphical layers can be seen as a spatial view extension, where would have been added many complementary layers (e.g., textual information). Information layers are a good way to separate treatings in image processing [6]. To distinguish attributes that are graphically relevant, we define a property on each attribute for a given spatial view, and whose value is a subset of all possible layers. We here consider two layers: textual and background, then LS={none, textual, background}. A Textual layer deals with all information as the form of alphanumerical characters in the image, that have weak spatial relationship (near); a background layer contains the rest (schematics, realistics) and none when the attribute has no graphical interest. Table 6 shows the graphical classifications for the toy database attributes.

Attribute	Graphical Classification
C.Street	textual
C.In	background
C.Out	background
C.Model	none
L.FrameRate	none
L.LineMaterial	none
E.StreetNumber	textual
E.Armour	background
E.PowerSupply	none

Table 6. Graphical Classifications

As an illustration, we address the problem of the spatial coherency into the graphical domain. An important problem in image processing is the graphical intersections: inter-layer (textual-background, e.g., symbol overlaping) and intra-layer (background-background). The first category does not directly concern spatial operators, but just graphical ones. We only deal with the second category.

We define a semantic-directed graphical coherency operator to ensure that graphical data are spatially coherent; such an operator works in a graphical domain. Let $SpatPredicate$ be a spatial predicate associated with spatial operator and operands, GDT be an image ADT, then: $OpGr_{SpatPredicate} : GDT \rightarrow [0, 1]$

This operator is directed by relevant spatial attributes given in table 6. For each operator and for each operand, we determine relevant attributes from the spatial closure. A reduced number of operators justify this combinatorial approach. As examples we define two graphical operators derived from borderline and adjacency spatial operators.

Borderline: Let $OpGr_{(Line \diamond Concentrator)}$ be a graphical operator devoted to connexion between line and concentrator. In and Out are the only relevant attributes useful for graphical treatings. The operator is then based on these attributes. Table 7 presents for such an operator an example of description steps. The global methodology then consists in searching for concentrators [6], and lines [13], and then graphically checking for a graphical coherency.

Step	Operator	Parameters
1	Image Croping	around concentrator
2	Angle Correction	horizontal alignment
3	Image Croping	left(In) or right(Out) part
4	Projection	horizontal
5	Threshold	average
6	Counting Regions	

Table 7. $OpGr_{(Line\diamond Concentrator)}$ **specification**

Adjacency: Let $OpGr_{(Line\lhd\rhd *)}$ be a graphical operator based on the adjacency operator. The aim of this operator is to detect a graphical adjacency configuration between Line and any graphical object at the background layer. Then the adjacency is performed between MOB Line and all possible MOBs in G_{BASE} to get all graphically relevant attributes. In our case, only Armour is a relevant attribute. Let us suppose such an operator works on a local zone, then as soon as the color of the possible Armour is detected, a possible EntryPoint may be near the line.

Real documents would require more sophisticated operators to deal with the image troubles. We only have presented a way to include spatial alphanumerical attributes, as a declarative form, to manage graphical treatings. The drawbacks of this method are that one graphical operator is required for one spatial operator and two operands at once, and can become hard to manage in the case of many operators (e.g., geographical map). As advantages, compared to other Raster-to-Vector applications, coherency checking is declarative. The control is then easier to manage.

4. Conclusion

In this article we have presented a way to improve the coherency checking in document analysis systems. This approach is based on an operator closure in the spatial domain. Alphanumerical attributes are then enable for a spatial operator result. We use these attributes in the graphical data level treatings, by using another subset to define graphical operators. The selection is done by defining graphical relevant attributes, similarly to a spatial view.

As perspectives we could envisage to improve the closure technique, on one hand by increasing the number of concepts and including holes or composite regions; and on the other hand, by performing the operator closure in the graphical level. Graphical closure is an improvement that has not yet been studied. In this case new concepts like the previous ones remain to be determined.

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