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Novel Indexing Method of Relations Between Salient Objects

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ABSTRACT

Since the last decade, image retrieval has been used in several application domains such as GIS, medicine, etc. Queries are formulated using different types of features such low-level features of images (histograms, color distribution, etc.), spatial and temporal relations between salient objects, semantic features, etc. In this paper, we propose a novel method for identifying and indexing several types of relations between salient objects. Spatial relations are used here to show how our method can provide high expressive power to relations in comparison to the traditional methods.

INTRODUCTION

During the last decade, a lot of work has been done in information technology in order to integrate image retrieval in the standard data processing environments. Image retrieval is involved in several domains [3, 6, 10, 13] such as GIS, Medicine, Surveillance, etc. where queries criteria are based on different types of features such as metadata [12, 14, 19], low-level features [1, 2, 16], semantic features [4, 15, 18, 23], etc.

Principally, relations between salient objects are very important. In medicine, for instance, the spatial data in surgical or radiation therapy of brain tumors is decisive because the location of a tumor has profound implications on a therapeutic decision [17, 20]. Hence, it is crucial to provide a precise and powerful system to express spatial relations.

In the literature, three major types of spatial relations are proposed [5]:

- Metric relations: measure the distance between salient objects [7]. For instance, the metric relation "far" between two objects A and B indicates that each pair of points A_i and B_j has a distance grater than a certain value δ.
- Directional relations: describe the order between two salient objects according to a direction, or the localisation of salient object inside images [8]. In the literature, fourteen directional relations are considered:
  - Strict: north, south, east, and west.
  - Mixture: north-east, north-west, south-east, and south-west.
  - Positional: left, right, up, down, front and behind.

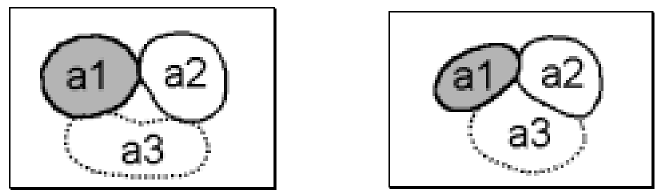
Directional relations are *rotation variant* and there is a need to have referential base. Furthermore, directional relations do not exist in certain configurations.

- Topological relations: describe the intersection and the incidence between objects [9, 11]. Egenhofer [9] has identified six basic relations: *Disjoint, Meet, Overlap, Cover, Contain, and Equal.* Topological relations present several characteristics that are *exclusive* to two objects (i.e., there is one and only one topological relation between two objects). Furthermore, topological relations have *absolute* value because of their constant existence between objects. Another interesting characteristic of topological relations is that they are transformation, translation, scaling, and zooming *invariant*.

In spite of all the proposed work to represent complex visual situations, several shortcomings exist in the methods of spatial relation computations. For instance, Figure 1 shows two different spatial situations of three salient objects that are described by the same spatial relations in both cases: topological relations: a1 Touch a2, a1 Touch a3, a2 Touch a3; and directional relations: a1 Above a3, a2 Above a3, a1 Left a2.

The existing systems do not have the required expressive power to represent these situations. Thus, in this paper, we address this issue and propose a novel method that can easily compute several types of relations between salient objects with better expressions. The rest of this paper is organized as follows. In section 2, we present our method for identifying relations. In section 3, we discussed how our method gives better results using spatial features. Finally, conclusions are given in section 4.

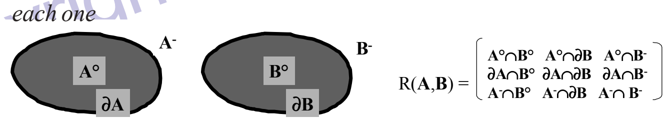
FIgure 1: Two different spatial situations



PROPOSITION

The 9-Intersection model proposed by Egenhofer [23], represents each shape "A" as a combination of three parts: *interior* **A°**, *boundary* **∂A** and *exterior* **A⁻**. The topological relations between two shapes are obtained by applying an intersection matrix between these parts (Figure 2). Each intersection is characterized by an empty (∅) or non-empty (¬∅) value.

Figure 2: The 9-intersection model: The topological relation between two shapes is based on the comparison of the three parts of each one



Our proposal represents an extension of this 9-Intersection model. It provides a general method for computing not only topological relations but also other types of relations such as temporal, spatial, etc. The idea shows that the relations are identified in function of features of shape, time, etc. The shape feature gives spatial relations, the time feature gives temporal relations, and so on. To identify a relation between two salient objects, we propose the use of an intersection matrix between sets of features.

Definition

Let us first consider a feature F. We define its intersection sets as follows:

- The ***interior*** $\mathbf{F^{\Omega}}$: contains all elements that cover the interior or the core of F. In particular, it contains the barycentre of F. The definition of this set has a great impact on the other sets. F^{Ω} may be empty (∅).

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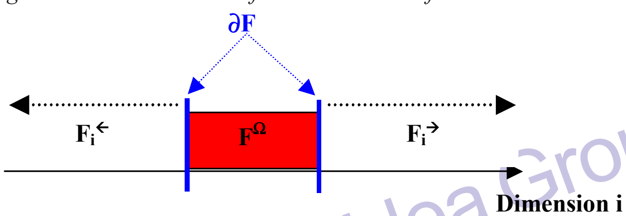
- The ***boundary* ∂F**: contains all elements that allow determining the frontier of F. ∂F is never empty (¬∅).
- The ***exterior* F**$^{-}$: is the complement of F^{Ω}È∂F. It contains at least two elements ⊥ (the minimum value) and ∞ (the maximum value). F^{-} can be divided into several disjoint subsets. This decomposition depends on the number of the feature dimensions.

For instance, if we consider a feature of one dimension i (such as the acquisition time of an image), two intersection subsets can be defined (Figure 3):

- **$F_i^{\leftarrow}$ (or inferior)**: contains elements of F^{-} that do not belong to any other intersection set and inferior to ∂F elements on the basis of i dimension.
- **$F_i^{\rightarrow}$(or superior)**: contains elements of F^{-} that do not belong to any other intersection set and superior to ∂F elements on the basis of i dimension.

If we consider a feature of 2 dimensions i and j (as the shape in a 2D space), we can define 4 intersection subsets (Figure 4):

Figure 3: Intersection sets of one-dimensional feature



- **$F_i^{\leftarrow} \cap F_j^{\leftarrow}$ (or inferior):** contains elements of F^{-} that do not belong to any other intersection set and inferior to F^{Ω} and ∂F elements on the basis of i and j dimensions.
- **$F_i^{\leftarrow} \cap F_j^{\rightarrow}$:** contains elements of F^{-} that do not belong to any other intersection set and inferior to F^{Ω} and ∂F elements on the basis of i dimension, and superior to F^{Ω} and ∂F elements on the basis of j dimension.
- **$F_i^{\rightarrow} \cap F_j^{\leftarrow}$:** contains elements of F^{-} that do not belong to any other intersection set and superior to F^{Ω} and ∂F elements on the basis of i dimension, and inferior to F^{Ω} and ∂F elements on the basis of j dimension.
- **$F_i^{\rightarrow} \cap F_j^{\rightarrow}$ (or superior):** contains elements of F^{-} that do not belong to any other intersection set and superior to F^{Ω} and ∂F elements on the basis of i and j dimensions.

More generally, we can determine intersection sets (2^n) of n dimensional feature. In addition, we use a tolerance degree in the feature intersection sets definition in order to represent separations between sets. For this purpose, we use two tolerance thresholds:

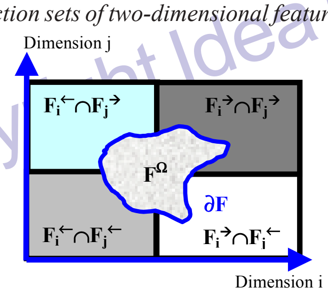
- Internal threshold $\boldsymbol{\varepsilon}^{i}$ that defines the distance between F^{Ω} and ∂F,
- External threshold $\boldsymbol{\varepsilon}^{e}$ that defines the distance between subsets of F^{-}.

To calculate relation between two salient objects, we establish an intersection matrix of their corresponding feature intersection sets. Matrix cells have binary values:

- 0 whenever intersection between sets is empty,
- 1 otherwise

For one-dimensional feature (such as the acquisition date), the following intersection matrix is used to compute relations between two salient objects A and B (Figure 5).

Figure 4: Intersection sets of two-dimensional feature



For two-dimensional feature (such as the shape) of two salient objects A and B, we obtain the following intersection matrix (Figure 6).

EXAMPLE

Figure 5: Intersection matrix of two objects A and B on the basis of one-dimensional feature

R(A, B) =	$A^{\Omega} \cap B^{\Omega}$	$A^{\Omega} \cap \partial B$	$A^{\Omega} \cap B^{\leftarrow}$	$A^{\Omega} \cap B^{\rightarrow}$
	$\partial A \cap B^{\Omega}$	$\partial A \cap \partial B$	$\partial A \cap B^{\leftarrow}$	$\partial A \cap B^{\rightarrow}$
	$A^{\leftarrow} \cap B^{\Omega}$	$A^{\leftarrow} \cap \partial B$	$A^{\leftarrow} \cap B^{\leftarrow}$	$A^{\leftarrow} \cap B^{\rightarrow}$
	$A^{\rightarrow} \cap B^{\Omega}$	$A^{\rightarrow} \cap \partial B$	$A^{\rightarrow} \cap B^{\leftarrow}$	$A^{\rightarrow} \cap B^{\rightarrow}$

Figure 6: Intersection matrix of two objects A and B on the basis of two-dimensional feature

$A^{\Omega} \cap B^{\Omega}$	$A^{\Omega} \cap \partial B$	$A^{\Omega} \cap B_1^{\leftarrow} \cap B_2^{\leftarrow}$	$A^{\Omega} \cap B_1^{\leftarrow} \cap B_2^{\rightarrow}$	$A^{\Omega} \cap B_1^{\rightarrow} \cap B_2^{\rightarrow}$	$A^{\Omega} \cap B_1^{\rightarrow} \cap B_2^{\leftarrow}$
$\partial A \cap B^{\Omega}$	$\partial A \cap \partial B$	$\partial A \cap B_1^{\leftarrow} \cap B_2^{\leftarrow}$	$\partial A \cap B_1^{\leftarrow} \cap B_2^{\rightarrow}$	$\partial A \cap B_1^{\rightarrow} \cap B_2^{\rightarrow}$	$\partial A \cap B_1^{\rightarrow} \cap B_2^{\leftarrow}$
$A_1^{\leftarrow} \cap A_2^{\leftarrow} \cap B^{\Omega}$	$A_1^{\leftarrow} \cap A_2^{\leftarrow} \cap \partial B$	$A_1^{\leftarrow} \cap A_2^{\leftarrow} \cap B_1^{\leftarrow} \cap B_2^{\leftarrow}$	$A_1^{\leftarrow} A_2^{\leftarrow} \cap B_1^{\leftarrow} \cap B_2^{\rightarrow}$	$A_1^{\leftarrow} \cap A_2^{\leftarrow} \cap B_1^{\rightarrow} \cap B_2^{\rightarrow}$	$A_1^{\leftarrow} \cap A_2^{\leftarrow} \cap B_1^{\rightarrow} \cap B_2^{\leftarrow}$
$A_1^{\leftarrow} \cap A_2^{\rightarrow} \cap B^{\Omega}$	$A_1^{\leftarrow} \cap A_2^{\rightarrow} \cap \partial B$	$A_1^{\leftarrow} \cap A_2^{\rightarrow} \cap B_1^{\leftarrow} \cap B_2^{\leftarrow}$	$A_1^{\leftarrow} A_2^{\rightarrow} \cap B_1^{\leftarrow} \cap B_2^{\rightarrow}$	$A_1^{\leftarrow} \cap A_2^{\rightarrow} \cap B_1^{\rightarrow} \cap B_2^{\rightarrow}$	$A_1^{\leftarrow} \cap A_2^{\rightarrow} \cap B_1^{\rightarrow} \cap B_2^{\leftarrow}$
$A_1^{\rightarrow} \cap A_2^{\rightarrow} \cap B^{\Omega}$	$A_1^{\rightarrow} \cap A_2^{\rightarrow} \cap \partial B$	$A_1^{\rightarrow} \cap A_2^{\rightarrow} \cap B_1^{\leftarrow} \cap B_2^{\leftarrow}$	$A_1^{\rightarrow} A_2^{\rightarrow} \cap B_1^{\leftarrow} \cap B_2^{\rightarrow}$	$A_1^{\rightarrow} \cap A_2^{\rightarrow} \cap B_1^{\rightarrow} \cap B_2^{\rightarrow}$	$A_1^{\rightarrow} \cap A_2^{\rightarrow} \cap B_1^{\rightarrow} \cap B_2^{\leftarrow}$
$A_1^{\rightarrow} \cap A_2^{\leftarrow} \cap B^{\Omega}$	$A_1^{\rightarrow} \cap A_2^{\leftarrow} \cap \partial B$	$A_1^{\rightarrow} \cap A_2^{\leftarrow} \cap B_1^{\leftarrow} \cap B_2^{\leftarrow}$	$A_1^{\rightarrow} A_2^{\leftarrow} \cap B_1^{\leftarrow} \cap B_2^{\rightarrow}$	$A_1^{\rightarrow} \cap A_2^{\leftarrow} \cap B_1^{\rightarrow} \cap B_2^{\rightarrow}$	$A_1^{\rightarrow} \cap A_2^{\leftarrow} \cap B_1^{\rightarrow} \cap B_2^{\leftarrow}$

Table 1 shows several spatial situations and their distinguished corresponding intersection matrixes. This demonstrates that each situation is identified by a different relation contrarily to traditional methods that consider all situations as similar (topological: "B disjoint A", directional: "B is below A"). Gray cells contain variant values in these situations; black cells contain invariant values in any situation; white cells may vary according to the situations. In fact, there are a number of hypotheses and rules used to eliminate impossible or invariant situations such as the intersection of two inferiors that is always not empty. This issue is not detailed in this paper.

DISCUSSION

Using our method, we are able to provide a high expression power to spatial relations that can be applied to describe images and formulate complex visual queries in several domains. For example, for Figure 1 that shows two different spatial situations between three salient objects a1, a2, and a3, our method expresses the spatial relations as shown in Figure 5. The relations R(a1, a2) and R'(a1, a2) are equal but the relations R(a1, a3) and R'(a1, a3) are clearly distinguished. Similarly, we can express relations between a2 and a3 in both situations.

Moreover, our method allows combining both directional and topological relation into one *binary* relation, which is very important for indexing purposes. There are no directional and topological relations between two salient objects but only one spatial relation. Hence, we can propose a 1D-String to index images instead of 2D-Strings [21].

CONCLUSION

In this paper, we presented our method to identify relations between two salient objects in images. We used spatial relations as a support to show how relations can be powerfully expressed within our method. This work aims to homogenize, reduce and optimize the representation of relations. It is not limited to spatial relations but it is also applicable to other types of relations (temporal, semantic, spatio-temporal, etc.).

However, in order to study its efficiency, our method requires more intense experiments in complex environment where great number of feature dimensions and salient objects exist. Furthermore, we currently work on its integration in our prototype MIMS [20] in order to improve image storage and retrieval.

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Table 1: Several spatial situations with corresponding intersections matrix

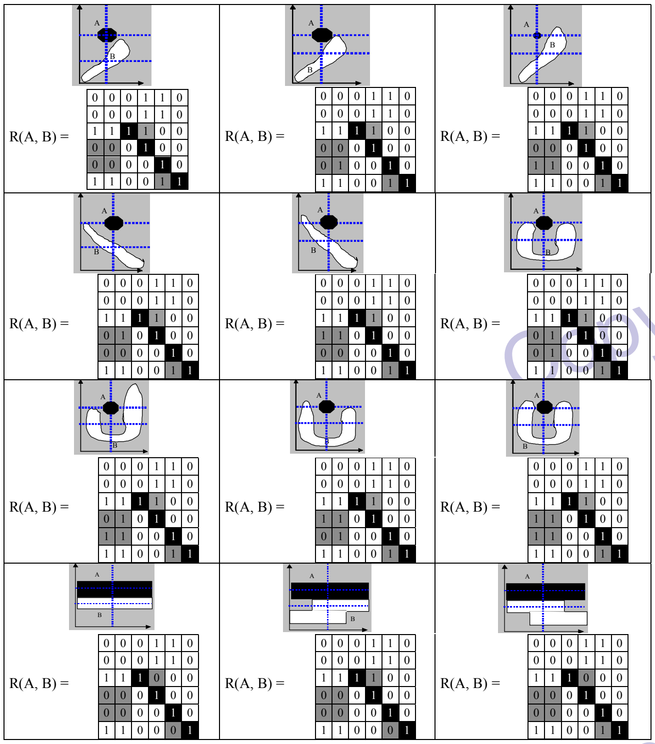
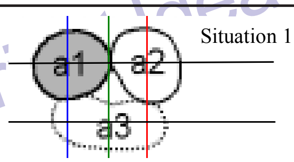
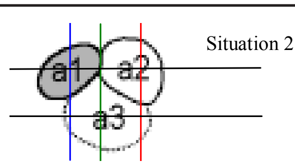


Table 1: Several spatial situations with corresponding intersections matrix.

Figure 7: Identified spatial relations using our method



$$R(a1, a2) = \begin{array}{|c|c|c|c|c|c|} \hline 0&0&1&1&0&0 \\ \hline 0&1&1&1&0&0 \\ \hline 0&0&1&0&0&0 \\ \hline 0&0&0&1&0&0 \\ \hline 1&1&0&1&1&0 \\ \hline 1&1&1&0&0&1 \\ \hline \end{array} \qquad R(a1, a3) = \begin{array}{|c|c|c|c|c|c|} \hline 0&0&0&1&0&0 \\ \hline 0&1&0&1&1&0 \\ \hline 1&1&1&1&0&0 \\ \hline 0&0&0&1&0&0 \\ \hline 0&0&0&1&1&0 \\ \hline 1&1&1&1&1&1 \\ \hline \end{array}$$



$$R'(a1, a2) = \begin{array}{|c|c|c|c|c|c|} \hline 0&0&1&1&0&0 \\ \hline 0&1&1&1&0&0 \\ \hline 0&0&1&0&0&0 \\ \hline 0&0&0&1&0&0 \\ \hline 1&1&0&1&1&0 \\ \hline 1&1&1&0&0&1 \\ \hline \end{array} \qquad R'(a1, a3) = \begin{array}{|c|c|c|c|c|c|} \hline 0&0&0&1&0&0 \\ \hline 0&1&0&1&1&0 \\ \hline 1&1&1&1&0&0 \\ \hline 0&0&0&1&0&0 \\ \hline 0&0&0&1&1&0 \\ \hline 1&1&1&0&1&1 \\ \hline \end{array}$$

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