An Approach in Spatial Databases

Mariana Stoeva[1] and Violeta Bozhikova[2]

Abstract –**This paper presents our work in the area of image retrieval in Image Databases for images saved by spatial similarity of extended objects location. We propose a new approach to description of the spatial location of extended objects. The approach is based on a geometric approximation. By the development of the proposed approach we enrich our former efforts for creation of effective method for image storage and retrieval from Spatial Databases.**

Keywords –**Image databases, spatial image databases, symbol description of extended objects, spatial similarity retrieval and spatial query processing.**

I. Introduction

The aim of this paper is to achieve a new response to the raised requirements of different applications to Spatial Image Databases (SIDB), namely attainment of invariance of query processing results with respect to arbitrary compositions of transformations. Our attention is directed to the object description methods by the spatial location of the extended objects contained in it. The image description in SIDB is in conformity with the next image retrieval from it by spatial query.

In real-world database applications, the rotation invariance is a basic issue because each image is captured and stored in agreement with a viewpoint which is implicitly dependent on an outside viewer who establishes a fixed scanning direction. Any translation of this viewpoint and/or any rotation of the image affect the direction relations between each pair of objects. In the recent literature, several approaches can be found whose aim is to provide a solution to the rotation invariance of the conventional indexing methodologies based on symbolic projections [2], [3], [4]. In [7] and [8] are presented approaches for speeding-up the time responses in databases which uses Spatial Access Methods (SAMs) to treat image content in conjunction with two well-known image matching methods, namely the editing distance on Attributed Relational Graphs (ARGs) and the Hungarian method for graph matching. It provides index support for the two most common types of similarity queries, referred to as range and nearest neighbour queries and has many desirable properties. However, in real application, it would also be able to find the images in the database that present a given pattern, even if it appears mirror reflected. An iconic indexing methodology is present in [6] which guarantees the rotation and reflection invariance of the image visual content, where it is described by direction relationships, which are view-based. This methodology does not recognize the similarity between two images when their corresponding symbolic descriptions (R-virtual images) have been extracted with respect to different rotation centres. In [9] we have proposed a geometric based structure which makes possible the extraction of spatial relations among domain objects that are invariant with respect to transformation such as translation, rotation, scaling. In [10] we propose an approach to symbol description of extended objects in SIDB and now we present its further development. By the proposed approach to spatial information description in an image we aim to achieve an effective storage of the image description information, effective query to SIDB processing, and efficient invariant with respect to transformations image retrieval from SIDB by spatial similarity.

By the development of the proposed approach for image spatial features description we enrich our former efforts to create an effective method for image storage and retrieval from SIDB through “query by image example” that gives an account of the spatial location of image domain objects and is invariant with respect of transformation compositions.

The solution of the task for image storage and retrieval from SIDB by spatial similarity lies on the following basic sub-solutions: consistency of original approximations of image objects area; determination of the spatial relations among domain objects, that are invariant with respect to transformations in images; determination of the similarity between spatial relations; determination of the measure of spatial similarity between relations of two images, spatial similarity algorithm whose results are determining for the spatial query processing.

II. Approximation of the Extended Image Object Area

The requirement for storage and spatial investigation efficiency imposes the condition for minimal dimension of the shape description of extended image object area. The objects are two-dimensional areas and the search for their minimal description is as a description of their approximation with suitable for a following processing rectangle form. The requirements for invariance with respect to transformation impose the perceived approximation to be close to the object area, as well as to be simply determined with respect to transformations. This means that an object is approximated with rectangle, whose sides concur with the same points of its approximations of the image objects area.

Definition 1. From all rectangles that include the area of an image object, MAR is the one whose area is minimal. If there are more than one such rectangles with minimal area, for approximating MAR is accepted this one, whose sides form smallest angle with the axis orientation of the object domain.

[1]Mariana Stoeva is with the Department of Computer Science and Technologies, Varna Technical University, Bulgaria, E-mail: mariana_stoeva@abv.bg

[2]Violeta Bozhikova is with the Department of Computer Science and Technologies, Varna Technical University, Bulgaria, E-mail: vbojikova2000@yahoo.com

This definition insures that for the approximating MAR determination are taken the coordinates of the same points of the area external contour independently from the possible transformations. The points from the contour of such determined approximating MAR of an object from an image keep their relative location towards its area centroid. MAR avoids the popular in the literature “diagonal imprecation” in two-dimensional area approximation by Minimal Boundary Rectangle (MBR). MAR is calculated by using object rotation around it’s centroid. The spatial data for each object include the absolute Decart coordinates of these 4 characterizing the object points (angle points of MAR) and of the object centroid, obtained from the points of its external contour.

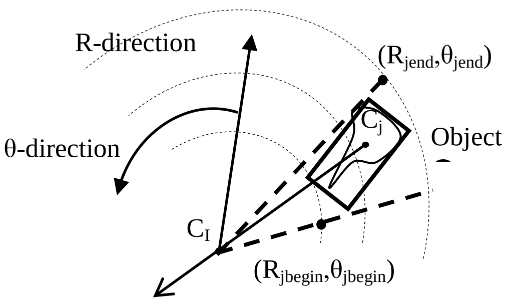

Fig. 1. Illustration of the approximations used

This information that is saved for each object, allows us to use ring sectors (MRS) determined by concentric circles for approximating the objects’ shape extent. Figure 1 illustrates the approximations used. By using this representation we determine, analogically to the orthogonal models, the well-known 13 relations in one linear (R) direction and one specifically used circle (θ) direction. We provide the transformation invariance of determination the atomic relations between two objects by utilizing the properties of the object and image centroids.

III. Image content description

By image symbol description we avoid the need of their repeated understanding. The memory that is necessary for the storage of the performed symbol image is insignificant in comparison with its physical performance. The query processing for image retrieval from SIDB uses only stored information for the image. The stored in SIDB information for the domain objects of each image contains as attributes symbol object names and 5 pairs of Decart coordinates that describe the spatial data of the object. The first one is the pair of object centroid coordinates, obtained from the coordinates of its area external contour. The next 4 are the coordinate pairs of the angle points of the approximating the object area MAR. The storage of absolute location of each object’s centroid is indispensable due to the fact that the relative spatial location of the stored information for each object’s area is preserved towards it. The image centroid, towards which the image objects preserve their relative spatial location, can be obtained from the stored centroids of an objects set from an image.

We accept that the domain objects describing symbol information is stored and arranged in alphabetic order of objects names. We accept that domain objects are named consistently through all images in DB and the images contain numerous examples of object type. The chosen SIDB model is object-relational and results in a general structure with general type of relational diagrams of two relations: “Images” and “Image objects”.

IV. Spatial similarity image retrieval in image database

This information that is saved for each object, allows us to use MRS determined by concentric circles for approximating the objects’ shape extent [8]. MRS of an object is obtained by the cross of concentric circles with center – the image centroid point, with passing through it strait lines. MRS minimally encloses the object area describing MAR and is determined by the minimums and maximums of its polar coordinates.

The spatial relations between each pair domain objects are determined in sense of conditions over the initial and final points of their MRS in two directions of a polar coordinate system [8]. By using this representation we determine, analogically to the orthogonal models [1], [4], the well-known 13 relations in one linear direction and one specifically used circle direction.

Definition 2. A triple like (Oj γ Oi) that is called an atomic spatial relation, where Oj, Oi $\in O_I$ are object names and $\gamma \in$ {<,>,|,:,=,[,(,],),/,\,%,#} is an operator. We use the notation (Oj γ_R Oi) to indicate that the pair of objects (Oj, Oi) belongs to relation γ in R-direction and (Oj γ_θ Oi) to indicate that the pair of objects (Oj, Oi) belongs to relation γ in θ-direction.

The defining of binary spatial relations is identical to those in [1] adapted to a polar system and it is presented in [8]. Applied for both directions here arise generally 169 spatial relations between two objects in two dimensions, by which the spatial content can be suitably presented. We provide the transformation invariance of determination the atomic relations between two objects by utilizing the properties of the object and image centroids.

The defining of binary spatial relations is identical to those, defined in the orthogonal models [8], adapted to a polar system, and it is presented in Table 1. The 7 symbols for spatial operators, used by Lee and Hsu in [5], are used here also, and 6 new symbol marks for operators indication (>, :, |, (,), #) are inserted.

Table 1: Determination of R-θ symbol spatial operators

Spatial relations	Conditions
Before A<B	end (A) < begin (B)
After A>B	begin (A) >end (B)
Touch A|B	end (A) = begin (B)
Touch inversely A:B	Begin (A) = end (B)
Overlap A/B	begin (A) < begin (B) < end (A) < end (B)
Overlap inversely A\B	begin (B) < begin (A) < end (B) < end (A)

Equally A=B	begin (A) = begin (B); end (A) = end (B)
Common start A[B	begin (A) = begin (B); end (A) > end (B)
Common inverse start A(B	begin (A) = begin (B); end (A) < end (B)
Common end A]B	begin (A) < begin (B); end (A) = end (B)
Common inverse end A)B	begin (A) > begin (B); end (A) = end (B
Include A%B	begin (A) < begin (B); end (A) > end (B)
Include inversely A#B	begin (A) > begin (B); end (A) < end (B)

Similarity distance is defined on the number of objects from the query, the common for both images objects, as well as on the similarity of their corresponding atomic relations and equations. Its values are in the diapason [0,1], where 1 is valid for image that completely satisfies the query and the value is 0 if they have no common objects.

According to our understanding for similarity and our desire the method to be independent of subjective interpretation, we put forward a formula for similarity evaluation that assesses the similarity between the common for both images objects and their corresponding atomic relations.

Definition 3. Let the query image is Q and the Image Database image is I. We define the similarity distance sim(Q,I) between Q and I by Eq.1 and sim(Q,I)$\in$ [0,1],

$$sim(Q,I)=\frac{1}{m}\left[C_o\, n+C_s\;\frac{1}{2n}\sum_j^n\sum_i^n\left(sim_{ji}(\gamma_R,\gamma_R')+\max\begin{Bmatrix}sim_{ji}(\gamma_\theta,\gamma_\theta')\\ sim_{ji}(\gamma_\theta^{o},\gamma_\theta')\end{Bmatrix}\right)\right]\quad for\ \forall\ n\neq 0$$
$$sim(Q,I)=0\quad for\ \forall\ n=0 \qquad (1)$$

where where: m=$\|O_Q\|$ is the number of objects in the query image, n=$\|O_Q \cap O_I\|$ is the number of the common for both images objects, $sim_{ji}(\gamma_R,\gamma_R')$ is the spatial similarity between the images Q and I for the object match (O_j,O_i) in R-direction, and $sim_{ji}(\gamma_\theta,\gamma_\theta')$ is the spatial similarity between the images Q and I for the object match (O_j,O_i) in θ-direction. $sim_{ji}(\gamma_\theta^{o},\gamma_\theta')$ is similarity between the spatial relations of image I and reflection image of the query Q for the object match (O_j,O_i) in θ-direction; and Co, Cs are coefficients (Co+Cs=1).

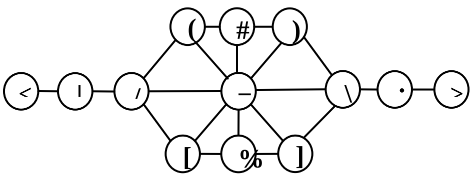

Fig. 2. Interval neighbor graph of the projection relations

This definition is different from the corresponding similarity distance from [8] by the including of the similarity between the spatial relations of image I and reflection image of the query Q in θ-direction ($sim_{ji}(\gamma_\theta^{o},\gamma_\theta')$) and the coefficients (Co,Cs). The processing of the image query to SIDB includes a filter that detaches as candidates only those images from SIDB that include objects from the query. The images – candidates are evaluated by spatial similarity for their proximity to the query by similarity algorithm $SIM_{R\theta}$.

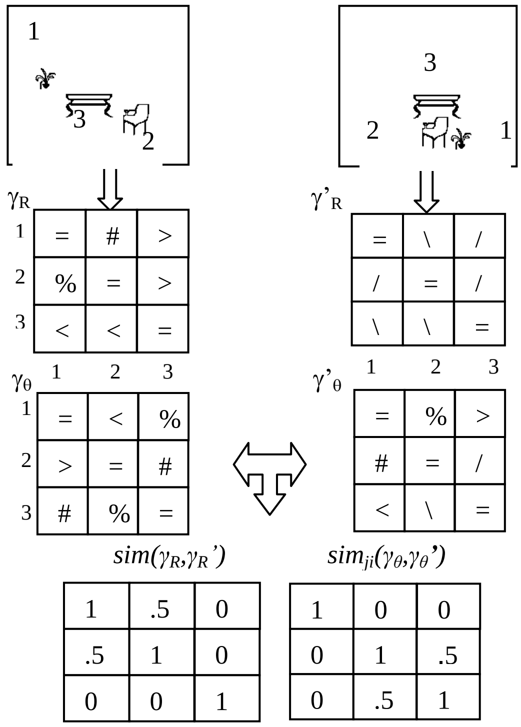

Fig. 3. An example, illustrating the obtaining of the spatial relations similarity, got between the three objects of two images

The similarity value $sim_{ji}(\gamma_1,\gamma_2)$ is defined for each pair (γ1, γ2) of spatial relations with equation:

$$sim(\gamma_1,\gamma_2)=1-d(\gamma_1,\gamma_2)/4) \qquad (2)$$

where the distance between two projection relations *d(γ1, γ2)* is determined as the length of the shortest way between their corresponding knots in the graph (Fig. 2.). The maximum value of the so determined distance in the graph is 6, and the minimum is 0. We accept that some degree of similarity exists if the distance is smaller than or equal to the average possible value of the distance.

The relations similarity in the two images Q and I for the pair of objects (Oj,Oi) in R-direction is indicated as $sim_{ji}(\gamma_R,\gamma_R')$, and as $sim_{ji}(\gamma_\theta,\gamma_\theta')$ in θ-direction.

An example, illustrating the obtaining of the spatial relations similarity, got between the three objects of two images, is presented by Fig. 3.

V. Experiments

The experiments that improve invariance to transformation compositions are published in [10]. We present hear the following experiment that investigates how the similarity distance detects smaller and bigger spatial differences between the images and how it reads the target understanding for spatial similarity. For these aims a test group 1 is used, which is presented in Fig. 4. The images in it are synthesized, and in one original image 6.1. smaller and bigger object and spatial differences are inserted as disposed, missing and alien to the query objects. The images include part of generally 24 named regional objects, whose iconic sketches are taken from the TESSA collection, or are created for variety of the test data. The chosen 6 extended objects in the original image 4.1 allow the generations of not big number of image variants differ by with gradually increasing intentionally inserted differences, for which similarity distances in possibly larger range shall be obtained. Images 1.2, 1.3, and 1.4 differ from the query by the disposed spatial position of one object. This object changes its relative spatial location in the consecutive variant. Images 1.5, 1.6, 1.7 and 1.8 differ by disposed two objects, and images 1.9, 1.10, 1.11, and 1.12 differ by the spatial position of three disposed objects. Images 1.4, 1.8, and 1.12 each have as additional difference one missing and one alien to the query object. Images 1.7 and 1.11 are transformation variants with composition (scaling, translation, rotation) respectively to 1.6 and 1.9.

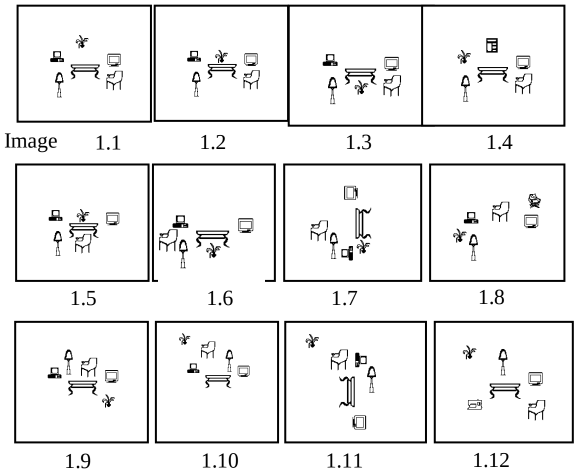

Fig. 4. Test images of Group 1, when image 1.1 is query by example

For the image query 4.1 and parameters $C_o=C_s=0.5$ the similarity ordering of the images in the group is as follows: {4.1, 4.2, 4.3, 4.5, 4.6, 4.7, 4.4, 4.9, 4.10, 4.8, 4.11, 4.12}. The obtained ordering corresponds completely to the expected one on the base of the introduced spatial differences in the group images. The values of the similarity measure change in the range [1; 0.6750] and decrease by the increase of the spatial differences (in disposed, missing and additional objects) between the images and the query. If the images are grouped by the number of the object differences, close, though different, values of the similarity distance are obtained for each object sub-group. The results, obtained for the similarity distance for the images of the sub-groups show strong dependence of the retrieval value on the number of differences, inserted in the image variant.

VI. Conclusion

The image spatial properties describing approach, proposed in this paper, implemented in a method for storage and retrieval of images from SIDB by spatial similarity of their domain objects achieves stability with respect to arbitrary compositions of transformations, shows completeness, correctness and sensitivity of the results. The method achieves very good effectiveness of information storage in SIDB and good efficiency of query processing. The experiments investigate it in details by use of various evaluations of the results and their comparison with other methods results. The experiments result demonstrates that the proposed approach is invariant with respect to transformations including reflection and its evaluation has stable behavior when enriching and detailing spatial relations among objects.

The main contributions are:

Utilization of new approximations, that provides short symbol description for storage in SIDB. This short information allows achieving invariance from transformations when determining the spatial relations in images.

Spatial similarity approach and distance measure for image retrieval from SIDB that recognize the shape, measures and mutual location of their objects. They detect transformed images and sub-images.

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