A New Approach to Symbol Description of the Spatial Location of Extended Objects in Spatial Databases

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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 SDB.**

Keywords **– Image databases, spatial databases, symbol description of spatial features, spatial query processing algorithms**

I. Introduction

The aim of this paper is to achieve a new response to the raised requirements of different applications to Spatial Databases (SDB), 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 SDB 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 affects 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 of symbolic projections [3], [4]. In [7], [8] and [5] are presented approachs 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 neighbor queries and has many desirable properties. However, in real application, it would also to be able to find the images in the database that present a given pattern, even if it appears mirror reflected. In [6] is present an iconic indexing methodology 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 centers. 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, and now we are going to propose 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 SDB processing, and efficient invariant with respect of transformations image retrieval from SDB by spatial similarity. The difficulties that appear when creating an approach that satisfactory implements all defined requirements motivates the hard work on the task for image storage and retrieval from SDB by similarity of the spatial location of their extended objects.

By the development of the proposed approach for image spatial properties description we enrich our former efforts for creation of effective method for image storage and retrieval from SDB 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. This method has to include the following basic components:

- An approach for determining the spatial attribute content that describes image spatial properties and the structure of its storage in SDB. It includes the well-grounded definition approximation named Minimum Area Rectangle (MAR). It is used to form the description of the spatial properties of domain objects;
- An approach for invariant determining of spatial relations built by the definition of the approximation Minimum object boundary Ring Sector (MRS), by the definition of spatial relations between objects, and by the definition of similarity between spatial relations;

Development of a mechanism for effective evaluation and processing of similarity spatial queries that recognize transformed images and sub-images, including definition of similarity distance, as well as an algorithm for its realization. The solution of the task for image storage and retrieval from SDB by spatial similarity lies on the following basic sub-solutions: consistency of original approximations of image

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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 two objects; spatial similarity algorithm whose results are determining for the spatial query processing. The solution uses two geometric of the extended objects by MRS, determined by concentrate circles. This second approximation is used for the determination of spatial relations between objects in a linear direction and in a specifically used circle direction.

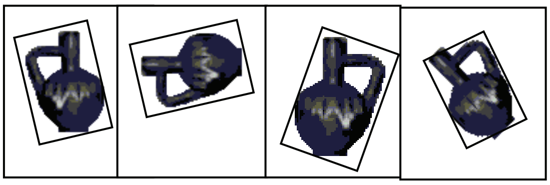

Fig. 1. Examples for determination of MAR of an object for its different transformation variants.

Invariance with respect to transformations in determining the atomic relations between two objects is provided by use of the circle direction properties, object centroid, (center of object weight) and image centroid. The paper is organized as follows: In Section 2 we propose the new approximation MAR and also an algorithm presented as MAR_{object}. In Section 3 we present the description used by us. In Section 4, for the purpose of similarity, we introduce descriptions of spatial relations, of spatial relation similarities, as well as similarity measure between two images. We publish a part of the experiments made and their results in Section 5. In Section 6 some conclusions are shown and further work aims are planned.

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. The first one defines the information that is stored as a symbol description for each image object and the second one gives ability for the spatial relations between image objects to be determined in such a way, that they stay invariant with respect to the transformations translation, rotation, scaling, reflection (symmetry), view point change, as well as arbitrary compositions of these transformations.

The basic idea of this method creation is that each image and its significant for the application objects will receive stored in SDB symbol description that includes symbol names of the objects, as well as the coordinates of 5 typical for their area shape points. The determination of the typical for the object area points from the external contour is invariant with respect to different transformations. This stored for each object information enables the use of next shape approximation external contour, independently from the transformation the image in which it is located suffers.

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 of area direction.

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 of the contour of the such determined approximating MAR of an object from an image keep their relative location towards its area centroid. Examples for approximation of an object that appears in different transformation variants of an image are illustrated at Fig.1. The such perceived approximation with MAR that encloses the object has minimal area and with removing the requirement: “its sides to be parallel to the corresponding coordinate axes “ and adding another one: “the area of MAR to be minimal” several effects are achieved. 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 of it’s centroid. The MAR is computed by an ordinary algorithm. This algorithm has linear **time complexity O(n)**. The angle points of MAR determine 4 typical for the object shape, dimension and location points. 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.

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 SDB uses only stored information for the image. The stored in SDB 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. An example of an image with 3 objects that illustrates the way the spatial properties of an image are symbolically described, is performed at Fig. 2.

	Object	centroid (x_0,y_0)	Absolute coordinates (x,y) Objects MAR
	Flower	(42, 80)	(39 , 64) (25, 87) (42, 97) (56, 74)
	Chair	(158, 134)	(142, 112) (142, 152) (174, 152) (174,112)
	Table	(98, 114)	(68, 100) (68, 130) (128, 130) (128, 100)

Fig.2. An Example of Image Symbol Description

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 SDB model is object-relational and results in a general structure with general type of relational diagrams of two relations: "Images" and "Image objects".

The stored symbol information of an image occupies space O(N) that is linear towards N, where N is the number of objects in it, in difference with other similar methods that use quadratic space $O(N^2)$ [6]

IV. Spatial similarity image retrieval in image database

A. Spatial Relations between Image Objects

This information that is saved for each object, allows us to use MRS determined by concentric circles for approximating the objects' shape extent [9]. 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 [9]. By using this representation we analogically to the orthogonal models [1], [4] determine the well-known 13 relations in one linear direction and one specifically used circle direction.

We use a triple like (O_j γ O_i) that is called an atomic spatial relation, where O_j, $O_i \in O_I$ are object names and $\gamma \in \{<,>,|,:,=,[,(,],),/,\backslash,\%,\#\}$ is an operator. We use the notation (O_j γ_R O_i) to indicate that the pair of objects (O_j, O_i) belongs to relation γ in R-direction and (O_j γ_θ O_i) to indicate that the pair of objects (O_j, O_i) 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 [9]. 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

B. Spatial Similarity Image Retrieval

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 2. 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]**,

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

$$sim(Q,I)=0\quad for\ \forall\ n=0$$

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,

$\mathbf{sim_{ji}(\gamma_R,\gamma_R')}$ is the spatial similarity between the images Q and I for the object match (O_j,O_i) in R-direction, and

$\mathbf{sim_{ji}(\gamma_\theta,\gamma_\theta')}$ is the spatial similarity between the images Q and I for the object match (O_j,O_i) in θ-direction.

$\mathbf{sim_{ji}(\gamma_\theta^{o},\gamma_\theta')}$ 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).

This definition is different of corresponding similarity distance from [9] 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 SDB includes a filter that detaches as candidates only those images from SDB that include objects from the query. The images – candidates are evaluated by spatial similarity for their proximity to the query by similarity algorithm $SIM_{R\theta.}$ It is invariant with respect to transformations of a query image and transformation variants of its sub-images. The algorithm for image matching has ***time complexity*** **O(N+Mn2)**, where N is number of tuples in relation "Image Objects", M (M<<N) is the number of results of filter step, n - the number of objects that are common for both the query and databases images.

V. Experiments

Experiments that investigate the efficiency of the method in 5 different aspects are executed. A collection of images in which terminal number of named objects is spatially situated is created as insert data. The symbol descriptions of the spatial properties of each image are extracted. Each experiment consists in execution of the spatial similarity algorithm for each pair of images from the test group. The similarity distance between each image pair from the test group is evaluated. The experiments evaluate the method stability with respect to transformations, make comparison with other methods: - θℜ-stribg [2] and virtual image [6] by quantity evaluation of spatial similarity retrieval from SDB. They evaluate also the adaptability of the spatial similarity algorithm and the way the similarity distance detects smaller and bigger spatial differences between images.

The effectiveness and the efficiency of spatial similarity retrieval algorithm are evaluated by using an expert-provided rank ordering of a test collection with respect to a set of test queries using the R_{norm} measure from [2]. This measure evaluate similarity order using one expert similarity arrangement. The results are compared with related to the subject published results.

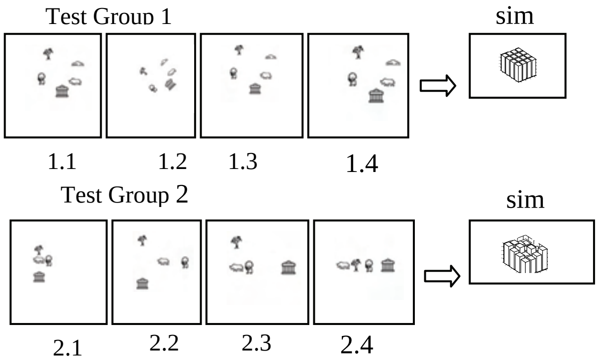

Fig. 3. Test images and spatial similarity measure (*sim*) on pairs of images of Group 1 and Group 2

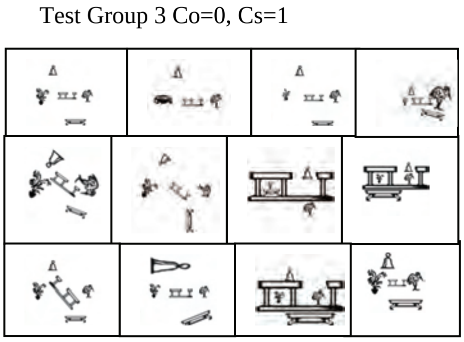

Fig. 4. Methods of Gudivada give iimages from Group 3 like spatially identical. Our approach gives measure *sim* ∈ [0.6, 1] for the same images, that approves its sensitivity.

VI. Conclusion

The image spatial properties describing approach, proposed in this paper, implemented in a method for storage and retrieval of images from SDB 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 SDB 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 main contributions are:

- Utilization of new approximations MAR for extended objects shape representation in order to provide invariance with respect to transformations of spatial relationships extraction from the image.
- Representations of an algorithm for computing a new approximation MAR.

Definition of a similarity measure between two images with its components, that is invariant of the transformations: translation, scaling, rotation and reflection.

References

[1] J. F. Allen, “Maintaining Knowledge about temporal Intervals”, Comm. ACM, vol. 26 pp.832-843 , 1983

[2] V. Gudivada, , V. Raghavan, “Design and Evaluation of Algorithms for Image Retrieval by Spatial Similarity”, ACM Trans. Information Systems, vol. 13(1) pp. 115-144, 1995

[3] F. Gudivada - θℜ-stribg: A geometry-based representation for efficient and Effective Retrieval of Images by Spatial Similarity, IEEE Trans. Knowledge and data engineering, vol. 10, no.3, pp.504-511, 1998

[4] E. Jungert, “Rotation Invariance in Symbolic Slope Projection as a Means to Support Spatial Reasoning”, Proc. Third Int’l Conf. Automation, Robotics and Computer Vision “ICARCV’95”, pp. 364-368, 1994

[5] G. Kunev V.Antonova, P.Vladimirova, “System Modeling via Databases”,ICEST2004, vol 2. pp. 277-278, Bitola, Macedonia, 2004

[6] G Petraglia, G. Sebillo , M., Tucci G. Tortora, “Virtual Images for Similarity Retrieval in Image Databases”, IEEE Trans. on knowledge and data engineering vol. 13(6) pp. 951-967, 2001

[7] E.G.M. Petrakis, Fast Retrieval by Spatial Structure in Image Databases, Journal of Visual Languages and Computing, Vol. 13, No. 5, pp. 545-569, October 2002

[8] E.G.M. Petrakis, “Content- Based Retrieval of Medical Images”, International Journal of Computer Research, Volume 11, , pp. 171-182, Number 2, 2002

[9] M. Stoeva, B. Rachev, “Retrieval by Spatial Similarity in Image Databases”, Proc. of 7th East European Conference, ADBIS 2003, pp.48-59, Dresden, Germany, http://www. adbis2003/ September 2003