POSTER: Invariant to Transformations Image Retrieval from Image Databases using a Boundary Based Description of Object Shape

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ABSTRACT
The basic problem of the methods for shape description of image objects is their dependence on the graphical transformations. In this paper we give boundary based method for shape description based on a multi-step criterion. We present a new approach for similarity shape retrieval from image database that achieves invariance of results with respect to transformations. We define and use a criterion to achieve invariant image object representation with respect to rotation. The approach includes original description of image objects shape of the type of multi-metric attribute stored in image database and a similarity distance definition for image retrieval processing that is invariant to reflection too. Our approach achieves results that are invariant with respect to arbitrary compositions of graphical transformations.

Keywords
Object shape description, image transform, image database, retrieval by similarity, content-based retrieval.

1. INTRODUCTION
Content-Based Image Databases (CBIDB) have been one of the most vivid research areas in the field of computer vision over the last 10 years. The main features that are used to describe the content of the images in the databases are colour, texture and shape of image objects. The increasing sizes of image archives, the requirements of the new appearing appliances and the fact that a few content based systems process shape queries make the further investigations over the shape feature necessary. The requirements for invariance of objects shape description that is extracted from preliminary not normalized images, with respect to all transformations (translation, scaling, rotation and reflection) are basic in the contemporary investigations [Jou01a].

Different methods for objects shape description are used in the existing visual systems and one of the most well-known is the group of the boundary based methods [Con00a]. As a common defect they all have the disadvantage to depend on the graphical transformations [Con00b]. In this paper we present a new approach based on a Multi-Step Criterion (MSC) that we use to achieve invariant image representation with respect to rotation. This MSC determines synonymously a “Start” Point (SP) from the external contour of an image object. For the purpose of the criterion a Recursive Selective Function (RSF) is defined and it is repeatedly applied with different parameters. The presented approach includes definition of RSF, the built on its base MSC for synonymous determination of a SP from the external contour of an image object, original description of image objects shape, and a similarity distance definition for image retrieval processing. We present some of our experiments that confirm the invariance with respect to transformations, completeness, correctness, and sensitiveness of the results of the similarity retrieval by shape from approach application.

2. AN APPROACH FOR SHAPE RETRIEVAL

The approach includes original description of image objects shape, based on multi-step criterion for determination of "start" for description of object shape point and a similarity distance definition that detects and finds out an image in the image database, that is equal in shape with the target image – query.

2.1 A Multi-Step Criterion for Determination of "Start" Point

Let for a given image object an ordered multitude of characteristic for its external contour points $V(\{v_i\}, i=1,\dots,n)$ is formed and let for these points a geometric measurement of feature p is made, that creates the ordered multitude $P(\{p_i\}, i=1,\dots,n)$, which is connected with V.

Let the function that obtains the multitude P containing the measurements of feature p from multitude V is indicated by $P=\varphi_p(V)$. And also let a selective function Max(V,P), that obtains the multitude $V_{max}\subseteq V$ by selecting those elements from the multitude V whose corresponding elements in P have value equal to the maximum one for the multitude P, is defined by (1).

$$V_{\max} = \mathrm{Max}(V,P) = \mathrm{Max}(V,\varphi_P(V)) = (\{v_i\}, p_i = p_{\max}) \quad (1)$$

Definition 1: A Recursive Selective Function (RSF) $\rho(V,P)$ is defined over the multitudes V and P by dependence (2) and determines a sub-multitude $V_p\subseteq V$ for which its corresponding sub-multitude $P' \subseteq P$ contains only maximum values as evaluation of the geometric measurement P.

$$V_P = \rho(V,P) = \begin{cases} V, & ako \quad V = V_{\max} \\ \rho(V_{\max}, \varphi_P(V_{\max})), & ako \quad V \neq V_{\max}, \end{cases} \quad (2)$$
$$where \quad V_{\max} = \mathrm{Max}(V,P) = (\{v_i\}, p_i = p_{\max})$$

The input of a recursion is imposed on the fact that if only one element from P is different from the others, the function Max(V,P) determines a sub-multitude with a smaller number of elements from that of the input multitude. For this selected sub-multitude the measurements of the feature P are already different as a rule. This imposes a pre-determination of the values of the geometric measurement for the points from the sub-multitude and applying of Max(V,P) again until it gives a result that is different from the input. This is repeated again and again until the function Max(V,P) stops to give a new result. In this way the whole potential of the function for a selection over a given measurement is utilized.

The recursive selective function is used for synonymous determination of the SP for description of image object's external contour. Such a description will be invariant to a possible rotation.

We suggest the choice of a start point from the multitude of points of the external contour to be made by introducing the MSC applied to the geometric features of the figure that will be applied consistently for three different measurements. If the criterion does not allow a synonymous choice after its third step, then it must be assumed that the figure is close to a regular polygon with number of top points equal to the number of points of the selected by the criterion sub-multitude. In this case as a "start" point is assumed the point from the selected sub-multitude that is closest to the axis $\overrightarrow{OX'}$. An example for the heaviest case for the criterion is the shape of the circle. Let $O(x_0,y_0)$ is the point - centroid of the points from the external contour $(\{C_{0i}\}, 1\leq i\leq k_0)$. The number of the points is $k_0=\|C_0\|$.The applying of the criterion must determine one of them as a SP independently from the angle of arbitrary rotation around point O.

In order to be solved the task for synonymous determination of one SP (noted Vsp) from the external contour of the object, the MSC is suggested that consists of consistent applying to the multitude of points of the external contour the specially deduced for this purpose recursive selective function for three measurements P over the geometry of the external contour points. These measurements are: the radius-vectors (**r**) of the points from the contour; the angle (Ω) that makes each point's radius-vector with the radius-vector of the next point in anticlockwise direction; the area (**S**) of a sector of the figure determined by the point – centroid and the next point.

Definition 2: The multi-step criterion for synonymous determination of one SP from the external contour of the object is given by the general record (3) of the consistent calls of the selective function.

$$\begin{aligned} V_S = \rho\{&[\rho(\rho(C_0,\varphi_r(C_0)), \\ &\quad \varphi_\Omega(\rho(C_0,\varphi_r(C_0))))], \\ &[\varphi_S(\rho(\rho(C_0,\varphi_r(C_0)), \\ &\quad \varphi_\Omega(\rho(C_0,\varphi_r(C_0)))))]\} \end{aligned} \quad (3)$$

If the MSC gives as a result a multitude of only one element ($k_s=1$), then it determines the Vsp=Vs for the external contour. In the other cases when $k_s>1$ it is assumed that the figure is a regular k_s-gon and as a SP for the contour the point that is closest to the axis $\overline{OX}$ is chosen. Some more interesting examples of shapes which have numerous points that meet all three conditions for maximum of the measurements in the criterion are illustrated in Figure 1.

The aim of determining these parameters in dependence of object shape by different measurements over the contours describing it, is the preparation of a concrete composition of transformations of the input data.

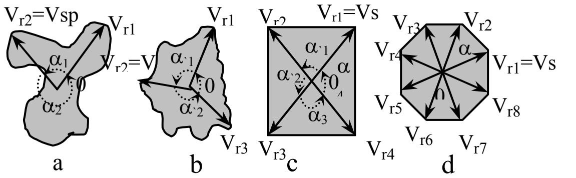


Figure 1. Examples for SP determination: a/Irregular shape, k_r=2, Vsp=V_{r2}; b/Irregular shape, k_r=3, Vsp=V_{r2}; c/For shape – rectangle, Vsp=V_{r1}; d/For shape – regular octagon Vsp=V_{r1};

2.2 Description of Objects Shape

From the external contour coordinates of an object F from a black-and-white image we determine the composition parameters: the external contour points centroid – point $O(x_0,y_0)$, the maximum Euclid distance from the centroid to the external contour points r_{0max}., and a SP for the external contour. Invariance of figure description with respect to the angle of arbitrary rotation is achieved by synonymous determination of a SP by the MSC. The input data information prepares a normalized representation of the object by dependences (4):

$$x'_{ji} = \frac{1}{r_{0\max}}(x_{ji} - x_0)\cos\alpha + \frac{1}{r_{0\max}}(y_{ji} - y_0)\sin\alpha \quad (4)$$
$$y'_{ji} = -\frac{1}{r_{0\max}}(x_{ji} - x_0)\sin\alpha + \frac{1}{r_{0\max}}(y_{ji} - y_0)\cos\alpha$$

where: (x_{ji}, y_{ji}) – Decart coordinates of the i-point in the j-contour, (x_0,y_0) – coordinates of the external contour centroid, r_{0max} – the maximum Euclid distance from the centroid to the external contour, α - the angle equal to the one between the radius-vector of the contour “start” pixel and the positive primitive axis X.

Image	Contours	Histogram description
		

Table 1. Illustration of obtaining an object shape description with L=96:

The histogram description of object shape that forms the multi-size index F= $((F_{\theta i}),\ 1 \le i \le l)$ is obtained from the contour coordinates transformed this way. Let a straight line start at the center of the coordinate system and let it have θ_i angle with the positive direction of X axis. This line crosses the contours C_j of the object in points with polar coordinates $F \cap \theta_i = ((r_{j1i}, r_{j2i}),\ 0 \le j < n)$, where : i is the serial number of the cross-points of the crossing axis ($1 \le i \le l$), l is the general number of the crossing axes ($L=3l$), r_{j1i}, r_{j2i} are the radius-vectors modules of the cross-points, $\theta_i = \theta_{i-1} + \pi/l$ and r_{0max} – the maximum Euclid distance from the centroid to the external contour.

Definition 3: The shape description $F(f_1,f_2,\ldots,f_{3l})$ is given by the dependence (5) and forms L- size index for shape that is stored in IDB.

$$F_{\theta i}(f_i, f_{i+l}, f_{i+2l}) = \begin{cases} f_i = \dfrac{1}{r_{0\max}}\max(r_{01i}) \\ f_{i+l} = \dfrac{1}{r_{0\max}}\min(r_{02i}) \\ f_{i+2l} = \dfrac{1}{r_{0\max}}\sum_{j=0}^{n-1}(-1)^j(r_{j1i} - r_{j2i}) \end{cases} \quad (5)$$

Table 1 presents the states of obtaining the shape description in form of multi-size attribute of medical object $F(f_1,f_2,\ldots,f_{L=96})$.

2.3 Image Retrieval from CBIDB

The technique for image retrieval from CBIDB as an answer of query by image example of object shape is consistent with the typical methodology for similarity query processing and includes the definition of a quadratic similarity histogram distance. The similarity distance presents the range of similarity between the normalized histogram descriptions of the query image and the next object image stored in CBIDB, evaluates the $D(Q,F) \in [0;1)$, and accounts value 0 for objects equal in shape. A similarity shape order may be obtained on the base of the similarity distance values of every image to the others.

$$D(Q,F) = \frac{1}{C^2 L}\min \begin{cases} \sum_{i=1}^{L}(q_i - f_i)^2 \\ (q_1 - f_1)^2 + (q_{L/3+1} - f_{L/3+1})^2 + \\ (q_{2L/3+1} - f_{2L/3+1})^2 + \\ \sum_{i=2}^{L/3}\left[\begin{array}{l}(q_i - f_{2L/3+2-i})^2 + (q_{L/3+i} - f_{L/3+2-i})^2 + \\ (q_{2L/3+i} - f_{3L/3+2-i})^2\end{array}\right] \end{cases} \quad (6)$$

Definition 4: Let the shape query is transformed into an image histogram description $Q(q_1,q_2,\ldots,q_n)$, and the image in the database has histogram description $F(f_1,f_2,\ldots,f_n)$, where q_i, f_i are histograms with size L and C is a presentation constant. The similarity distance between Q and F for the examined retrieval model is determined by Equation (6).

3. EXPERIMENTAL RESULTS

Our algorithms are implemented in MatlabR12 and C+ + and are evaluated on test database of 2000 binary images from an image collection. The experimental collection includes also some modified by us images of the same object, transformed by composition of translations and intentionally added changes in the objects contours. Their corresponding attributes, stored in IDB that contain description of object shape, have dimension L=96 and L=12 for l = 32 and l=4. Experiments had been implemented that investigated the invariance, completeness, correctness, and sensitiveness of the results from the similarity retrieval by shape. Some representative examples are illustrated below.

Query  and **Result:**

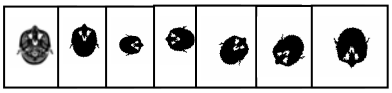


Figure 2. Similarity ordering of retrieved images

Figure 2 illustrates a test demonstration of numerous experiments whose purpose is the evaluation of the approach stability with respect to transformations both in extraction of image shape description and image retrieval from CBIDB. A set of objects are used that are obtained from transformation variants of the original. An expert evaluation should account as equal all images in the set. The original image with target value of the parameter L=12 is used as a query. It accounts the similarity distance between the query and each one image from the set and an ordering of the variants by similarity follows. The results – the values of the similarity distance $d \in [0, 10^{-7}]$ prove the approach stability with respect to arbitrary combined compositions of transformations.

Query  and **Result:**

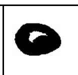
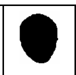
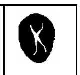
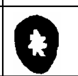
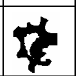
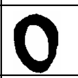
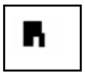
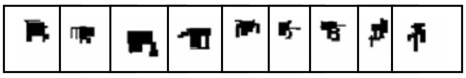
Result					
Similarity Distance D×10^{-4}	0	0	42	45	45
Result					
Similarity distance D×10^{-4}	145	175	388	434	

Table 2. Similarity ordering for L=96.

The detected minimal differences in the similarity distance values in the range of 10^{-8} present the "strength" of the similarity distance, i.e. it is a low bounding sensitive object similarity distance.
The next experiment presented with Table. 2 is focused on the similarity strength of the similarity distance. By this experiment, we aim to ascertain the similarity distance behavior when smaller or bigger errors in the shape of the internal and external contours of the transformed images are introduced. We use some modified images of the same object transformed by translation and rotation and/or with changed internal and external contours. The replies of the k-query for k = 9 are obtained for value of the parameter L = 12. The experiments show good sensibility of the similarity distance to recognize big as well as small differences of objects shapes.

The correctness of the results was investigated in comparison also with the results of other no invariant methods, such as the one of The Axially-parallel Rectangles of [Con00b]. Copies of the images published in [Con00b] are used for the experiment.

Query  **and Results:**

a/ 

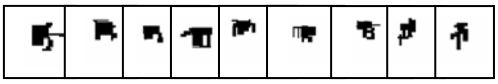
b/ 

Figure 3. Similarity ordering according [Con00b] and our approach.

Fig.3.a/ presents the results - answer of the query from [Con00b]. Fig3.b/ presents the results of our approach for L=96. $R_{norm}(sys)$ [Jou01b] measure for quantity evaluation of the similarity ordering results is used to evaluate the result of this experiment. In this case for the method a/ $R_{norm}(sys)_6 = 0.7031$, and for our approach $R_{norm}(sys)_6 = 0.7812$, that means that our results are closer to the user's ordering.

4. CONCLUSIONS

The presented approach is investigated in details by use by use of various evaluations of the results of the implemented experiments. Our conclusions are:

- The developed approach is stable with respect to arbitrary compositions of transformations;
- The approach application is efficient as it achieves completeness, correctness, and sensitiveness of the results of the similarity retrieval by shape;
- The approach achieves a very good effectiveness of information storage in IDB and a good effectiveness of query processing to IDB.

5. REFERENCES

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