Shape Similarity for Biometrical Analyses

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Abstract – **This paper presents an approach for evaluation the shape similarity of image objects. The approach was developed for use in biometrical and medical image databases. This approach has the advance to achieve results that are invariant with respect of arbitrary compositions of graphical transformations and point of view change of the images processed. The approach includes an original objects image shape description in the type of multi-sized attribute stored in image data base and a technique to find and determine in the database an image that is equal in shape to the target image – query.**

Keywords – **Biometrics, Biometrical Systems, Content Based Image Data bases, Shape Similarity.**

I. INTRODUCTION

The presented approach was developed for use in biometrical and medical Image Data Bases (IDB). Both areas are developing rapidly especially at the moment.

The growth of the biometrical analysis systems applications needs great requirements, systematized in [5] to the systems for identification and verification based on biometrical analysis of fingerprint images, palm images, signatures, eye retina, cochlea, etc. In the medical field, images, and especially digital images, are produced in ever-increasing quantities and used for diagnostics and therapy. Three large domains can instantly be stated for the use of content-based access methods: teaching, research and diagnostics. Other very important fields are the automatic annotation/ codification of images and the classification of medical images.

There are a number of fields close to the medical domain where the use of content-based access methods to visual data have been proposed as well or are already implemented. The article [3] gives an overview of available literature in the field of content-based access to medical image data and on the technologies used in the field. The contemporary investigation interest is concentrated on the development of content-based IDB in the context of the object-relational model and the philosophy of "query by image example". Most of the available systems are, however, from academia. Some well-known examples include Candid [1], Photo book [4] and Netra [2] that all use simple color and texture characteristics to describe the image content. Most of these systems have a very similar architecture for browsing and archiving/ indexing images comprising tools for the extraction of visual features, for the storage and efficient retrieval of these features, for distance measurements or similarity calculation and a type of Graphical User Interface.

The approach includes original description of image objects shape in type of multi-metric attribute stored in image database and a technique for detecting and finding out in the database an image that is equal in shape with the target image – query. The query processing is supported by the definition of a distance that is conformable to the application specific and gives an account of the difference in shapes of two objects.

The experiments of the approach that investigates biometrically the shape of biometrical and medical image objects proves its invariance with respect of arbitrary transformations, as well as the ability of the defined distance to detect both big and small differences in image objects shapes.

II. SHAPE DESCRIPTION OF THE IMAGE OBJECTS

The information, kept in the image database is a description of the shape of the image objects. The extraction of the description includes: transformation of the input data and forming of the shape attribute in the form of a histogram. Figure 1 illustrates the process of getting the histogram description of the feature 'object shape' for the two types of objects respectively. The transformation of the input data is done by a composition of transformations, whose parameters are determined by geometric measures over the external contour of the image object and especially created for that purpose recursive selective function. The invariance of the description with respect to the transformations is achieved by a preliminary transformation with a composition, whose parameters are determined by the shape specificity of the image object.

The input data are biometrical (palm and cochleae) and medical digital images. The biometrical collection can include images of left or right hand taken from different points of view. The objects of interest are derived through segmentation by one of the existing methods from the assigned on pixel level image The image is transformed into a black-and-white image, containing only the identified object – F. For every object we get the external contour C_0, and the internal contours C_j using the common algorithm of going from up to down and from the left to the right.

From black-and-white images, containing an object F by using the coordinates of the external contour we get the parameters of the composition: the centroid of the points from the external contour – the point $O(x_0,y_0)$) and the maximal Euclidean distance from the centroid to the points of the external contour r_{0max} and the angular polar coordinate α of a point of the centroid that we call "starting" point [6]. Invariance of a shape description with respect to the angle of

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arbitrary rotation is achieved simply by determining the "starting" point from the external contour. We choose a starting point from all the points of the external contour by introduction of a criterion (applied to the geometric features of the figure), that we apply for three different measures P of the geometry of the points from the external contour [6]. After the transformation of the input data we get a normalized presentation of the contours of the object. The transformation is presented by the equations (1):

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

where: (xji, yji) - Carthesian coordinates of the i-th point into the j-th contour, (x_0,y_0) - coordinates of the centroid of the external contour, r_{0max} – the maximal Euclidean distance from the centroid to the points of the external contour, α - the angle between the radius-vector of the "starting" pixel of the contour and the positive direction of the X axis.

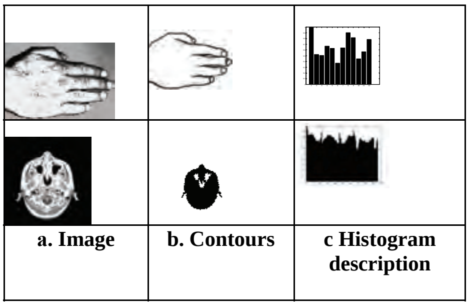


Fig.1: Illustration of obtaining an object shape description:
a. image; b. contours; c. histogram description

From this way transformed contour coordinates the multidimensional index $F=((F_{\theta i}), 1\leq i\leq l)$, describing the object shape in type of histograms is obtained. The value of the histogram is formed by the intersection points of the contours with the four axes, passing through the coordinate system beginning and situated on uniform steps $\Delta\theta = \pi/4$ in a circular direction. Let the line passing through the beginning of the coordinate system and subtending with the X axis angle θ_i intersects the contours of the object C_j in points with coordinates $F\cap\theta_i=((r_{j1i}, r_{j2i}), 0\leq j <n)$, where: i is the consecutive number the intersecting axis $(1\leq i \leq l)$, l is the overall number of the intersecting axes. Shape description $F(f_1,f_2,\ldots,f_{3l})$ is given by equations (2), forming 12-dimensional attribute for shape, that is kept in the database.

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

III. DATABASE QUERY PROCESSING

Te technique for image retrieval as a response of a query by image example is conformed with the typical methodology for similarity query processing, including the definition of a quadratic histogram similarity distance. It measures the semantic of the histogram description and is invariant to all kinds of transformation compositions. The similarity distance shows the degree of similarity between the normalized histogram description of the query image and the image in the database. Its value is $D(Q,F) \in[0;1)$ and its value is 0 for objects with identical shape. Using the similarity distance between every image and all others a order of shape similarity can be obtained.

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. The retrieval value between Q and F for the examined retrieval model is determined by equations. (3):

$$D(Q, F) = \frac{1}{C^2 L}\min \begin{cases} \sum_{i=1}^{L}(q_i - f_i)^2 \\ (q_1 - f_1)^2 + (q_{L/3+1} - f_{L/3+1})^2 + \\ (q_{2L/3+1} - f_{2L/3+1})^2 + \\ (q_i - f_{2L/3+2-i})^2 + \\ \sum_{i=1}^{L/3}(q_{L/3+i} - f_{L/3+2-i})^2 + \\ (q_{2L/3+i} - f_{3L/3+2-i})^2 \end{cases} \qquad (3)$$

IV. EXPERIMENTAL RESULTS

The developed shape-research approach is experimentally investigated by use of the data of two application areas. The purpose of the first one is the identification and verification of personal data in DB containing images of unique in biometrical sense human organs as palms and cochleae. The second application uses stored numeric images for medical purposes and deformation investigations, ranges of diversions from norms, contusions, etc. Our algorithms are implemented in MatlabR12 and are evaluated by experiments on images from a test database. The images are transformed to be black-and-white and to get dimensions 64×64. All images that we use in this paper are from the experimental author's collection and they are made by the authors.

Figure 2 illustrates a test demonstration of numerous experiments whose purpose is the evaluation of the approach stability with respect of transformations both in extraction of image shape description and image retrieval from IDB. The presented experiment is with image data used for neurological investigations. A set of objects are used that are obtained from transformation variants of an 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 and after an account of the similarity distance between the query and each one image from the set follows an ordering of the variants by similarity. The results – the values of the similarity distance d∈[0, 10^{-7}] prove the approach stability with respect of arbitrary combined compositions of transformations. 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.

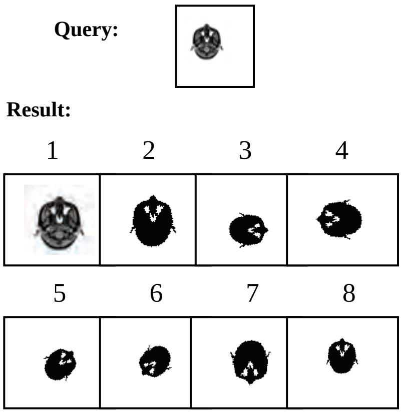


Fig.2: Similarity ordering

The next experiment presented here with Fig. 3 uses data from histological investigations and 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. A medical image of an object is used as a simple query model. We made 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 two values of the parameter L = {12,96 }.

Query: 

Result:

Result					
Similarity Distance $D\times10^{-4}$	0	0	42	45	45
Result					
Similarity distance $D\times10^{-4}$	145	175	388	434	

Fig. 3: Similarity ordering for parameter L=96.

The expectations for the values of the similarity distance, respectively the similarity ordering, were confirmed. Fig. 3 illustrates the data of the results obtained by this experiment as well as the ordering by shape similarity of 9 images for L=96.

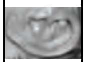
Original image 			
Distance - d	d=0	d=0	d=0
			
d=2. 10^{-6}	d=2. 10^{-6}		
Original image 			
Distance - d	d=0	d=12. 10^{-8}	d=12. 10^{-8}

Fig. 4: Similarity order of different images of palms and cochleae of one person.

						
Distance - d	0	2 . 10^{-6}	0.6240	0.1977	0.0510	0.1855

Fig. 5: similarity distance between 6 different images of palms

					
Distance - d	0	12 . 10^{-8}	0.1670	0.0086	0.0248

Fig. 6: similarity distances between 6 different images of cochleae.

The experiments for applicability of the approach in biometrical databases includes two types of experiments. The first type of experiments has the purpose to examine the stability of the approach with respect to transformations by image retrieval. The results from one of the test groups are illustrated in Fig.4 for the two types of objects respectively. The results from the five groups show differences in the values of the similarity distance in the order of 10^{-6} and prove the stability of the approach with respect to arbitrary combined compositions of transformations and its ability to test the identity of shapes of palms and cochlea regardless of the point of view.

The second type of experiments is focused on the measuring of the similarity distance and representing the degree of shape similarity quantitatively. Fig.5 illustrates the computed similarity between 1 query image and 6 other images of palms, one of which is a transformed variant of the query. The group includes also a second palm query image snapshot from the opposite side. Fig.6. illustrates the computed similarity between one query-image and 5 other images of cochleae, one of which is the same right cochlea image and the other one is a left cochlea image of the same person. The results confirmed our expectations for the values of similarity distance and similarity order - they show as the most similar image the image that is identical with the query, followed directly by an image that has a small change in the external contour. The represented results show the desired behavior of our similarity model with respect to the given answers and demonstrate its advantages.

V. CONCLUSION

The implemented experiments of the presented approach investigate it in details by use of various evaluations of the results and their comparison with the results from other methods. The following basic conclusions may be formulated from the obtained through the experiments results:

- The developed approach for storage and retrieval of images from IDB by similarity of the shape of the contained objects is stable with respect of arbitrary compositions of transformations;
- The approach application is efficient as it achieves completeness, correctness, and sensitiveness of the results from the similarity retrieval by shape from IDB;
- The approach achieves a very good effectiveness of information storage in IDB and a good effectiveness of query processing to IDB;
- The biometrical approach that investigates the objects shape from different types of medical images may be very useful when applied for various medical purposes. However, each concrete application has a specific that may require additional adaptation of the approach in order maximum efficient results to be obtained.

Main contributions:

- new content-based approach which provides access to the object shape of significant for various areas of biometrical and medical image objects;
- Achievement of results that are invariant with respect of arbitrary compositions of graphical transformations.

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