A Geometry based Approach for Identification of Image Objects

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Abstract - **In this paper we present a new technique for identification of images from image collection that are similar by shape to the objects they contain. Our shape similarity retrieval model is based on histogram description of object shape that is independent on translation, scale, rotation and reflection transformations.**

Keywords – **image database, query processing, content based image retrieval, shape description**.

I. INTRODUCTION

The content based image information systems require a new visual approach for query specification, new indices for data assignation and new methods for similarity retrieval between the query and the target. These are more and more challenging tasks due to the extreme increase of the number and sizes of image archives.

In this paper we present a new technique for image retrieval from image collection that are similar by shape to the objects they contain. Our shape similarity retrieval model is based on histogram description of object shape that is independent on the translation, rotation and reflection transformations. This description forms a multi-dimensional index for the object shape with a relatively low dimension. The defined similarity distance reflects the understanding for shape similarity. We illustrate a similarity query processing architecture consistent with our model. The carried out experiments demonstrate the applicability and the efficiency degree of the proposed technique.

II. SHAPE DESCRIPTION

The following methods are used in the existing visual systems for shape description: boundary based geometrical methods; geometrical region based methods and region based transform methods, described in [4]. Most of the methods derive object shape description with no dependence on translation [2]. Just a few of the shape descriptions are invariant in case of rotation and scaling [1],]3].

The method, proposed in this paper describes object shape but this description does not depend on possible translation, scale and rotation of the object and has relatively low dimension.

The object of application interest is derived through segmentation by one of the existing methods from the assigned on pixel level image. We assume that a gray scale image of dimension m×m contains only one object $F:\Im m\times\Im m\rightarrow\Re$. The pixel based description of F is geometrically described by n contours of the object F=(Cj , 0≤ j ≤n-1). The object contours C_0, C_1, …,C_n are obtained by a common algorithm. The contours C_j are joint multitudes of pixels assigned by their k-number of coordinates C_j=((xji, yji), 1≤ i ≤ k), where C_0 is the external k-dimension contour of the object and C_1, C_2..., C_{n-1} are possible internal contours. Fig. 1 illustrates the obtainment of histogram object shape description.

The transformation uses the centroid features of the image object extracted from object external contour C_0 according the equasion (1). The centoid (X_0, Y_0) keeps its relational spatial location with respect to the contour points regardless of translation, rotation and scaling transformation.

$$X_0=\frac{1}{k}\sum_{i=1}^{k}x_{0i} \qquad Y_0=\frac{1}{k}\sum_{i=1}^{k}y_{0i} \tag{1}$$

The coordinate system center is conventionally displaced to the point - centoid (X_0, Y_0). The external and the internal contours Decart coordinates are transformed. The transformation is presented by Eqs. (2) and (3).

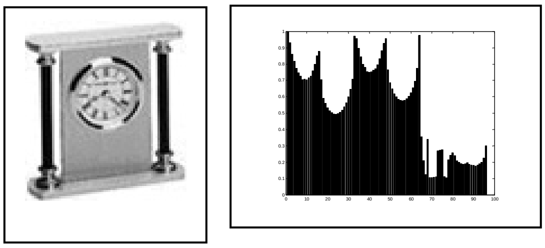

Fig.1: Segmented object and histogram shape description.

$$x'_{ji}=\frac{1}{r_{0\max}}(x_{ji}-x_0)\cos\alpha+\frac{1}{r_{0\max}}(y_{ji}-y_0)\sin\alpha$$
$$y'_{ji}=-\frac{1}{r_{0\max}}(x_{ji}-x_0)\sin\alpha+\frac{1}{r_{0\max}}(y_{ji}-y_0)\cos\alpha \tag{2}$$

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Angle α is defined by the angle (polar coordinate) of the "start" point of the external contour. This "start" point is uniformly determined invariantly to rotation by using

$$r_{ji} = \begin{cases} +\sqrt{x_{ji}'^{2} + y_{ji}'^{2}}, & \text{за } y'_{ji} > 0 \text{ или } y'_{ji} = 0, x'_{ji} > 0 \\ -\sqrt{\sqrt{x_{ji}'^{2} + y_{ji}'^{2}}}, & \text{за } y'_{ji} < 0 \text{ или } y'_{ji} = 0, x'_{ji} < 0 \end{cases}$$

$$\theta_{ji} = \begin{cases} \operatorname{arctg} \dfrac{y'_{ji}}{x'_{ji}}, & \text{за} \quad x'_{ji} \neq 0 \quad 0 \le \theta_{ji} < \pi \\ \pi/2, & x'_{ji} = 0 \end{cases} \qquad (3)$$

recursive selective function (4). For an ordered multitude $V(\{v_i\}, i=1,\ldots,n)$ from a typical for the external contour of the object points is obtained the ordered multitude $P(\{p_i\}, i=1,\ldots,n)$ from geometric measurements of the feature p for these points of V. These measurements are the radius-vectors of the points from the external contour, the angles and the areas of the segments they make with the centroid.

$$V_P = \rho(V,P) = \begin{cases} V, & ako \quad V = V_{\max} \\ \rho(V_{\max}, \varphi_P(V_{\max})), & ako \quad V \neq V_{\max} \end{cases},$$

$$\textit{където}: \qquad V_{\max} = \mathrm{Max}(V,P) = (\{v_i\}, p_i = p_{\max}) \qquad (4)$$

The maximal Euclidian distance from the centroid to the external contour points is determined $r_{0max} = \max|r_{0i}|$. Then a guiding for the outer contour pixel is determined. A first- rate criterion for guiding pixel assignation is its coordinate to satisfy the requirement $|r_{0i}| = r_{0max}$. In case of more than one pixel available, for which $|r_{0i}| = r_{0max}$, a more complicated criterion is utilized, accounting the number and coordinates of the points of the contour between the maximums. A rotation of the contour C_j around point (X_0,Y_0) with angle α comes after so that the specified as guiding pixel lies on the positive direction of the 0X axis after the rotation. This rotation aims the orientation of every one contour in one and the same way $C_j=((r_{ji}, \theta_{ji}), 1\le i \le k, 0\le \theta_{ji} <\pi), 0\le j \le n-1$. From this way transformed contour coordinates the multidimensional index $F=((F_{\theta i}), 1\le i \le l)$, 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 axes, passing through the coordinate system beginning and subtending an angle θ_i with the positive direction of the X axis. The angle θ $(0\le\theta_i<\pi)$ varies from 0 up to π by uniform step $\Delta\theta = \pi/l$, where the overall number l of the axes may have a value $2^1, 2^2, 2^3,\ldots, m$. In order to describe all pixels $\Delta\theta \approx \pi/m$, for images with dimension $m\times m$, the number l of the axes intersecting the contours is $l \approx m$.

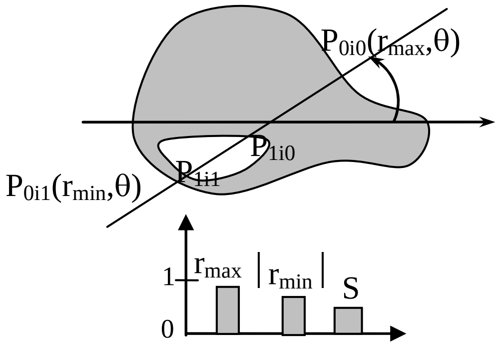

Fig.2. Illustration of the evaluation of 3 columns of histogram description.

The fact, that an arbitrary line intersects any contour C_j even number of times is used. Let the line passing through the beginning of the coordinate system and subtending with the X axis angle θ_i =const intersects the contour C_j in P_j points were P_j is an even number: $F\cap\theta_i=((r_{jis}), 1\le s\le P_j, P_j \ge 2)$. Eq. (5) presents three histograms obtained for one axis of intersection, where i is the consecutive number the axis θ_i=const $(\theta_i=\Delta\theta(i-1)\ 0\le\theta_i <\pi)$ $(1\le i\le l)$ and l is the number of axes.

$$F_{\theta i}(f_i, f_{l+i}, f_{2l+i}) = \begin{cases} f_i = C \quad \max_r((r_{0ip}), 0 \le p \le p_{0n}) \\ f_{l+i} = C \quad \left|\min_r((r_{0ip}), 0 \le p \le p_{0n})\right| \\ f_{2l+i} = C \; \dfrac{1}{2} \displaystyle\sum_{j=0}^{n} \sum_{p=0}^{p_{jn}} (-1)^j (-1)^p r_{jip} \end{cases} \qquad (5)$$

Object shape description gets the mode $F(f_1,f_2,\ldots,f_n)$. It forms the multidimensional index for shape, stored in the databases. The multidimensional index for shape have dimension 3l. The maximal index dimension for image with dimension $m\times m$ is 3m, or, for image 512×512 the maximal dimension is 1536 D, that is a relatively low dimension for such an image.

III. SIMILARITY RETRIEVAL

Content based query processing imposes the definition of a similarity evaluation criterion, named retrieval value or similarity distance. 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 Eqs. (6), where C is a constant of presentation and L is the description lenghth.

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

(6)

The used quadratic functions are already approved as appropriate distance functions for similarity search. In the chosen by us similarity distance the first two components account the external contours similarity and the third component accounts the similarity of all the internal contours. In our understanding for similarity, consistent with the medical appliance, the similarity weight of the external contour is much higher than that of the internal contours similarity. The computation frame of the process of similarity calculation and an example of similarity between two objects are shown in Fig. 3. The distance between the shape descriptions of the two objects alarm clocks is shown too.

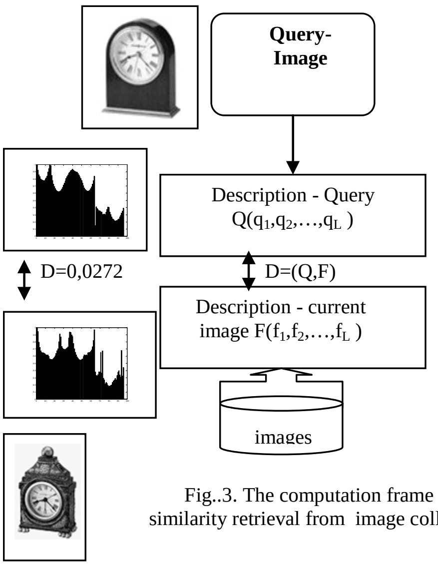

Fig..3. The computation frame of similarity retrieval from image collection

IV. EXPERIMENTAL RESULTS

Our algorithms are implemented in MatlabR12 and C+ + and are evaluated on test database of 2000 images from a medical image collection. The images are transformed in order to get dimensions 256×256, and their index with dimension 3l = 384 for l = 128. The presented results illustrate the desired behavior of our similarity model with respect to the returned answers. The results demonstrate good filter selectivity and performance in the high-dimensional image space. As a sample query we chose the image of object - human arteriosclerosis coronary artery existing in DB. The collection includes also some modified by us images of the same object, transformed by translation or rotation and also images of the same transformed object but with different number of internal contours added. The experiments for robustness of the access confirmed the results invariance to arbitrary transformations. Fig.4 shows the results for an evaluated similarity for 4 objects from the experimental data. The experiments show good sensibility of the similarity distance to recognize big as well as small differences of objects shapes.

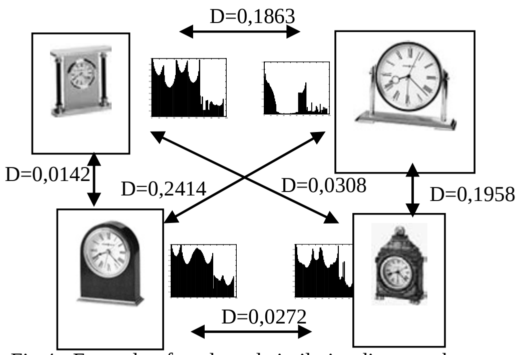

Fig.4.. Example of evaluated similarity distances between 4 objects shape descriptions.

V. CONCLUSIONS

In this paper we presented a geometrically based shape similarity model. This model is invariant with respect of the transformations translation, scaling, rotation and reflection and possesses invariability and stability. We illustrated the process of similarity calculation consistent with our model. The carried out experiments demonstrate the applicability and the efficiency degree of the proposed technique.

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