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SHAPE MATCHING AND RECOGNITION USING HYBRID FEATURES FROM SKELETON AND BOUNDARY

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ABSTRACT

This paper presents a novel approach for effective matching of similar shapes from skeleton and boundary features. The features identified from the shape are the junction points, end points, and maximum length from single pixel pruned skeleton of the shape. Another two features identified from the boundary are junctions and boundary length of the shape. These five features are then used for shape matching. We tested these features on Kimia shapes dataset and tools dataset. The matching process from these features has produced good results, showing the probable of the developed method in a variety of computer vision and pattern recognition domains. The results demonstrate these features are rotational and translation invariant.

GENERAL TERMS

Object Recognition

INDEXING TERMS

Mathematical Morphology, Boundary, Features, Shape Matching.

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1. INTRODUCTION

Shape representation and recognition is an important problem in computer vision. Shape representation plays a major role in classification and recognition of similar objects. Many shape representation and matching techniques have been developed [1, 2]. Some of them use boundary-based approaches, which include polygonal approximation, chain code, boundary curvature scale space and Fourier descriptors. But the boundary based schemes do not describe a shape's interiors directly.

Another group of shape representation and matching algorithms are region based. A feature vector can be used describe a shape such as area, compactness, eccentricity, and Euler number. The main drawback of these techniques is much information is lost about the given shape. But the success of these methods strongly depends on the choice of the features and their extraction. It is also complicated to deal with shape's missing parts.

The skeleton is essentially a one pixel thick line that passes through the centre or medial axis, of an object. An accurate skeleton hold important properties that makes it suitable for pattern recognition, computer vision, and image compression applications. A skeleton of an object integrates geometrical and topological features of the object, is a significant shape descriptor for object recognition [3]. Currently there are many methods for an image skeletonization [13, 14]. Most of these methods are either pixel based or non-pixel based methods. The pixel based methods include thinning [15, 16] and distance transform [16]. In the non-pixel based methods, cross section the skeleton is analytically derived from the border of the image. The two types of non-pixel based methods are cross section [17] or Voronoi diagrams [18]. These methods determine the symmetric points of a shape without the intermediate step of the grassfire propagation. There are more than 300 skeletonization methods have been proposed [15], but the improvement is still required.

The original shape object can be reconstructed from its skeleton by the union of the maximal disks defined by the medial axis [4]. Serra extended the morphological skeleton to objects sampled on a discrete hexagonal grid [5]. Morphological skeleton transform is a morphological transformation that describes a shape by its natural geometrical representation [6]. The morphological skeleton representation both provides information of geometrical structure of an image and to reduce the entropy of an image for data compression.

All skeletons obtained from the medial axis are not single pixel thickness. Sometimes the skeletons may be disconnected. A graph based approach [10] is used to reduce the skeleton as single-pixel thickness. But most of times the skeletons have redundant skeleton braches that may lead to disturb the topology of the skeleton's graph. The skeleton pruning is the common approaches to eliminate redundant skeleton branches [9, 19].

For shape matching boundary junctions of shape plays an important role for object detection [20]. Shape similarity based on skeleton matching typically performs better than contour or other shape descriptors in the presence of partial occlusion and articulation of parts [7-11].

In this paper we focus on 2D shape matching using both skeleton and boundary features based on the mathematical morphology.

This rest of this paper is organized is as follows, section-2 describes the basic morphological definitions. In Section-3 the features extraction process from skeleton and boundary. Section-4 shows the matching process. Section-5 describes the results and discussions and finally section-6 has a brief conclusion.

2. BASIC DEFINITIONS

Mathematical morphology is a tool for extracting image components that are useful in the representation and description of region shape, such as boundaries and skeletons. The two basic morphological operations are dilation and erosion. The other operations like opening, closing, etc. are derived from these two basic operations [21].

2.1 Skeleton

The skeleton of an image *A* can be expressed in terms of erosions and openings as shown below.

$$S(A) = \bigcup_{k=0}^{k} S_k(A) \tag{1}$$

With $S_k(A) = (A \ominus kB) - (A \ominus kB) \circ B$

Where *B* is a structuring element, and $(A \ominus kB)$ indicates k successive erosions of *A*.

Most of the skeletons obtained from the above method don't produce single-pixel thickness skeletons. A graph based algorithm, removal of redundant skeleton points (RRSP) [10] reduces the skeleton to single-pixel thickness.

Even though sometimes the single-pixel skeleton of an object often contains many spurious branches which are due to boundary irregularities, which negatively influences the performance of object recognition based on skeletal structure. Hence, it is necessary to eliminate these short branches on the skeleton we use Discrete Curve Evaluation (DCE) [7]. The main idea of this method is partitioning the object's contour into segments, followed by eliminating the skeleton points whose generating points are on the same segment. The sample shape image, its single-pixel pruned skeleton, and its boundary are shown in the following figure 1.

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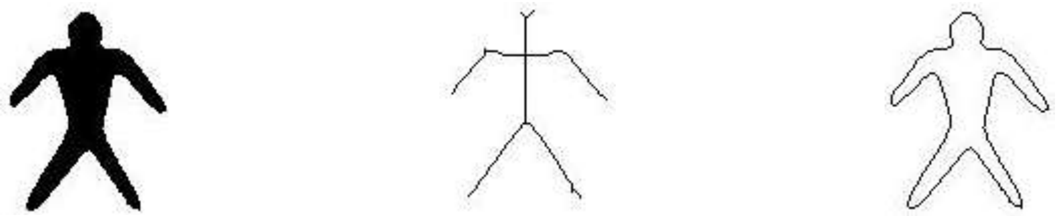

(a) (b) (c)

Fig. 1: (a) sample shape image, (b) Shape's skeleton, and (c) Shape's boundary.

The length of the skeleton can be expressed as

$$S_l = \sum_{i=1}^{m} \sum_{j=1}^{n} S[i,j] \tag{2}$$

Formally the End Pints, Junction Points and Curve points are defined as follows:

End Point (EP): It is a point of one-pixel width digital curve, if it has a single pixel among its 3×3 neighbor.

Junction Point (JP): It is a point of one-pixel width digital curve, if it has more than two curve pixels among its 3×3 neighbor.

Curve Point (CP): It is a point of one-pixel width digital curve, if it has two curve pixels among its 3×3 neighbor.

1 0 0	0 1 0	0 0 1	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0
0 **1** 0	0 **1** 0	0 **1** 0	0 **1** 1	0 **1** 0	0 **1** 0	0 **1** 0	1 **1** 0
0 0 0	0 0 0	0 0 0	0 0 0	0 0 1	0 1 0	1 0 0	0 0 0
A	***Φ₁(A)***	***Φ₂(A)***	***Φ₃(A)***	***Φ₄(A)***	***Φ₅(A)***	***Φ₆(A)***	***Φ₇(A)***

Fig. 2. The Structuring Elements (SEs) for the end points: The fundamental SE is *A* and its rotations are *$\Phi_1(A)$, $\Phi_2(A)$, …, $\Phi_7(A)$*

0 1 0	1 0 1	0 1 0	0 0 1	0 0 0	1 0 0	0 1 0	1 0 1
1 **1** 1	0 **1** 0	0 **1** 1	0 **1** 0	1 **1** 1	0 **1** 0	1 **1** 0	0 **1** 0
0 0 0	0 0 1	0 1 0	1 0 1	0 1 0	1 0 1	0 1 0	1 0 0
B	***$\Phi_1(B)$***	***$\Phi_2(B)$***	***$\Phi_3(B)$***	***$\Phi_4(B)$***	***$\Phi_5(B)$***	***$\Phi_6(B)$***	***$\Phi_7(B)$***
0 1 0	0 0 1	1 0 0	0 1 0	0 0 1	1 0 0	0 1 0	1 0 1
0 **1** 1	1 **1** 0	0 **1** 1	0 **1** 0	1 **1** 0	0 **1** 1	1 **1** 0	0 **1** 0
1 0 0	0 0 1	0 1 0	1 0 1	0 1 0	1 0 0	0 0 1	0 1 0
C	***$\Phi_1(C)$***	***$\Phi_2(C)$***	***$\Phi_3(C)$***	***$\Phi_4(C)$***	***$\Phi_5(C)$***	***$\Phi_6(C)$***	***$\Phi_7(C)$***

Fig. 3. The Structuring Elements (SEs) for the junction points: The fundamental SE is *B* and its rotations *$\Phi_1(B)$, $\Phi_2(B)$, …, $\Phi_7(B)$*; *C* and its rotations *$\Phi_1(C)$, $\Phi_2(C)$, …, $\Phi_7(C)$*.

Each end point in a digital curve corresponds to the one of eight configurations of the structuring element *A* and its rotations by 45^o as shown in figure 2. An end point can be represented by one of these eight representations. The end point can be extracted from a skeleton X, erode with each SE, *A* and by its rotations sequence $\Phi_i(A)$, taking the sum of all the results and detecting from the sum S the pixels the value of which is 1, i.e. they match end configurations only once. Then these points are labeled as end points.

$$EP(X) = \bigcup_{p \in X} \{S(p) = 1\} \tag{3}$$

Where,

$$S = \sum_i X \ominus \Phi_i$$

At the same time, we are able to identify the junction points as well as the curve points. The junction points match the end point configuration at least three times, while the curve points match them at least twice. Hence,

$$JP(X) = \bigcup_{p \in X} \{S(p) \geq 3\} \tag{4}$$

and

$$CP(X) = \bigcup_{p \in X} \{S(p) = 2\} \quad (5)$$

2.2 Boundary

The boundary of an image *A* can be defined as

$$\beta(A) = A - (A \ominus B) \quad (6)$$

The length of the boundary can be expressed as

$$\beta_l = \sum_{i=1}^{m} \sum_{j=1}^{n} \beta[i,j] \quad (7)$$

3. FEATURE EXTRACTION

The skeleton and boundary features are extracted from the following procedure. The extracted features are used to matching of similar shapes.

Procedure for finding feature vectors

Step 1. Find Skeleton using basic mathematical morphology technique from equation (1).

Step 2. Remove redundancy pixels using Removal of Redundant Skeleton Points (RRSP) algorithm [10].

Step 3. Prune the skeleton using Discrete Curve evaluation (DCE) [11].

Step 4. From the single-pixel pruned skeleton measure the three features; end pints, junction points, and maximum length of skeleton form equations (2), (3) and (4).

Step 5. From the boundary of image measure two features; junction points and boundary length from equations (4) and (7).

4. SHAPE MATCHING

Shape matching is the process through which two or more shapes are associated, generally in a point-by-point fashion. The five features from the skeleton and boundary are used to match a particular shape using minimum distance classifier. The minimum distance classifier is used to classify an unknown object to classes which minimize the distance between the object data and the class in multi-feature space. This distance is defined as an index of similarity so that the minimum distance is identical to the maximum similarity.

Here, we used Standard deviation Euclidian distance metric for finding the minimum distance shown in equation (8). The minimum distance is measured between each pair of feature vectors *x* and *y* in training set and test set respectively for recognition.

$$d = \sqrt{(x-y)V^{-1}(x-y)^T} \quad (8)$$

Where *V* is the $n \times n$ diagonal matrix whose j^{th} diagonal element is $S(j)^2$, where *S* is the vector of standard deviations and n is the number of objects.

5. RESULTS & DISCUSSIONS

The experiments are carried out on two popular shape datasets Kimia-99 and Tools.

The Kimia dataset has 99 shape images of 9 categories. The retrieved results of first 10 matches from 99 objects are shown in figure 4. It is observed that for the given query image, the retrieved shapes are completely matched for first 7 results. But in the last row we detected a sea fish instead of tool as shown in figure 2. In the remaining matches of 8, 9, and 10 some of them are miss matched which are shown in bold.

The tools database contains 48 images from 8 objects. The retrieval results of first 5 matches of from 48 objects are as shown in figure 5. It shows that our features are very effective for matching of similar shapes.

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CONCLUSION

In this paper we described a simple shape matching using the features from both skeleton and boundary. From the experimental results we observed that our features are effective for shape matching, because of the combined features from the boundary and skeleton of the shape. These features are rotational and translation invariant.

Query Iamge	Top 10 similar shapes									
	1	2	3	4	5	6	7	8	9	10
	0	0.2640	0.4047	0.6820	0.8005	0.9917	1.1150	1.3966	1.4318	1.4589
	0	0.3156	0.4456	0.5560	0.5766	0.5799	1.0085	1.0341	1.0753	1.2222
	0	0.5040	0.6182	0.7112	0.9763	1.0637	1.0884	1.1182	1.1942	1.2019
	0	0.1634	0.2453	0.5537	0.6012	0.6929	0.7284	0.8597	0.8739	0.9877
	0	0.6973	0.8324	1.0319	1.2718	1.3026	1.3328	1.3397	1.4621	1.5583
	0	1.0091	1.0357	1.0713	1.1116	1.1288	1.2459	1.4441	1.5531	1.5787
	0	0.7703	1.2624	1.3103	1.377	1.3295	1.3670	1.6118	1.7174	1.8797
	0	0.4287	0.4804	0.5155	0.5203	**0.8791**	0.8889	0.9428	1.1555	1.1576

Fig. 4. Kimia data set: each row shows instances of a different object category. The first 10 matches are shown.

Query Image	Top 5 similar shapes matched for the given query image				
	1	2	3	4	5
	0	0.4945	0.9014	1.2594	1.4592
	0	0.5085	0.5323	1.7428	1.7829
	0	0.7580	1.3361	1.6381	2.0476
	0	1.1103	1.1874	1.5376	1.5388
	0	0.6969	1.1564	1.2278	1.3780

Fig. 5. Tools data set: each row shows instances of a different object category. The first 5 matches are shown.

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REFERENCES

[1] D. Zhang and G. Lu, “Review of shape representation and description techniques,” *Pattern Recognition*, vol. 37, no. 1, pp. 1-19, 2004.

[2] S. Loncaric, “A survey of shape analysis techniques,” *Pattern Recognition,* vol. 31, no. 8, pp. 983-1001, 1998.

[3] H. Blum, “Biological shape and visual science”, *J. Theror. Biol*. Vol. 38, pp. 205-287, 1973.

[4] P. Lantuejoul, “Morphological Image Analysis: Principle and Applications”, Springer, Berlin, 1999.

[5] J. Serra, “Image analysis and mathematical morphology”, *Academic press*, New York, 1992.

[6] P. Margos, R. Schafer, “Morphological skeletons representation and coding of binary images”, *IEEE Trans, Acoust. Speech Signal Process,* Vol. 34(5), 1228-1244, 1986.

[7] C. Aslan, A. Erdem, E. Erdem, and S. Tari. “Disconnected skeleton: shape at its absolute scale”. *IEEE Trans. PAMI*, 2008.

[8] X. Bai and L. Latecki. “Path similarity skeleton graph matching”. *IEEE Trans. PAMI*, 30(7):1282–1292.

[9] X. Bai, L. Latecki, and W.-Y. Liu. “Skeleton pruning by contour partitioning with discrete curve evolution”. *IEEE Trans. PAMI*, 29(3):449–462, 2007.

[10] T. Sebastian, P. Klein, and B. Kimia. “Recognition of shapes by editing their shock graphs”. *IEEE Trans. PAMI*, 26(5):550–571, 2004.

[11] K. Siddiqi, A. Shokoufandeh, S. Dickinson, and S. Zucker. “Shock graphs and shape matching”. *Intl’ J. of Com. Vis.*, 35(1):13–32, 1999.

[12] G. Rama Mohan Babu, Dr. A. Srikrishna, Dr. B. Raveendra Babu, and M. Ramesh. “A rotational invariant connected skeleton with reduced skeleton points”, *International Journal of Research and Reviews in Computer Science (IJRRCS)*, Vol. 2, No. 3, pp.659-663, June 2011.

[13] V. Vijaya Kumar, A. Srikrishna, et al., “An Improved Iterative Morphological Decomposition approach for image skeletonization”, *Journal of Graphics Vision and Image Processing of ICGST*, vol. 8, issue 1, pp.47-54, 2008.

[14] V. Vijaya Kumar, A. Srikrishna, et al., “A New Skeletonization Method Based On Connected Component Approach”, *International Journal of Computer Science and Network Security*, vol 8, No.2, pp.133-137, 2008.

[15] L. Lam, S.W. Lee, and C.Y. Suen, “Thinning Methodologies-A Comprehensive Survey,” *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 14, pp.869-885, 1992.

[16] M. Unser, Local linear transforms for texture measurements. *Signal Process*. 11, pp.61-79, 1986.

[17] T. Pavlidis, “A Vectorizer and Feature Extractor for Document Recognition,” *Computer Vision, Graphics, and Image Processing*, vol. 35, pp. 111-127, 1986.

[18] R.L.Ogniewicz and O. Kubler, “Hierarchic Voronoi Skeletons”, *Pattern Recognition*, vol. 28, pp.343-359, 1995.

[19] K. Siddiqi, A. Tannenbaum, S. W. Zucker. Hyperbolic "Smoothing" of Shapes. In *ICCV*, pp.215-221, 1998.

[20] Bo Wang, Xiang Bai, Xinggang Wang, Wenyu Liu, Zhuowen Tu. “Object recognition using Junctions”, ECCV 2010, Part V, LNCS 6315, pp. 15-28, 2010.

[21] G. Rama Mohan Babu, Dr. B. Raveendra Babu, et all, “An error free compression algorithm using morphological decomposition”, *IEEE Int. Conf. on RACSS-2012,* pp. 33-36, 2012.

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