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Paper Authors
Ms.A.Venkata Lakshmi, Mr.K.Vamshi, Mr. K. Nandu, Mr. S.Dileep

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SHAPE MATCHING AND OBJECT RECOGNITION USING COMMON BASE TRIANGLE AREA

Ms.A.Venkata Lakshmi[1], Mr.K.Vamshi[2], Mr. K. Nandu[3], Mr. S.Dileep[4]

[1]Assistant Professor, Department of ECE, CMR Institute of Technology, Medchal, Hyderabad.

[2,3,4]Bachelor's Student, Department of ECE, CMR Institute of Technology, Medchal, Hyderabad.

ABSTRACT-Shape matching and object recognition are essential areas of study in computer vision, with applications spanning robotics, medical imaging, augmented reality, and security systems. One of the key challenges in these domains is developing efficient and reliable algorithms that can accurately recognize and match objects despite variations in scale, rotation, and orientation. This project explores a novel approach to shape matching and object recognition using a geometric feature known as the common base triangle area. The method focuses on decomposing complex shapes into simple,manageable geometric components, making the matching process both efficient and scalable.In this approach, we extract key triangular structures from the contours of objects and calculate the areas of triangles that share common bases. This technique leverages the principle that objects with similar shapes will have a consistent relationship between their base triangles, even if the objects are distorted or rotated. By comparing these geometric features, the algorithm can match shapes and recognize objects with high precision. The approach is robust to transformations like translation, scaling, and rotation, making it ideal for real-world applications where objects may not appear in a standardized orientation. The proposed method is evaluated on various datasets, comparing its performance against traditional shape matching techniques. The results demonstrate the algorithm's ability to achieve high accuracy in object recognition tasks, while also providing computational efficiency. In addition, the method's scalability makes it suitable for large-scale object recognition systems, such as automated image classification or real-time object tracking in video surveillance.

Keywords: Recognition, Detection, CBTA

1.INTRODUCTION

Shape matching and object recognition are fundamental problems in the field of computer vision. These tasks are crucial for enabling machines to interact with the real world by identifying and understanding objects in their environment. Over the years, numerous algorithms have been proposed to tackle these problems, each with varying degrees of success in terms of accuracy, speed, and robustness. Traditional methods often rely on complex feature extraction techniques or high-dimensional representations of objects. While these methods can be effective in some cases, they are often computationally expensive and may struggle to handle variations in object appearance, such as changes in scale, rotation, or partial occlusion.The goal of this project is to present a novel method for shape matching and object recognition that addresses some of the limitations of traditional approaches. Specifically, we focus on a geometric feature known as the **common base triangle area**.

Fig 1. Geometrical shapes

This concept is rooted in computational geometry and aims to simplify the matching process by breaking down complex shapes into smaller, more manageable components: triangles. By focusing on the areas of these triangles that share a common base, the algorithm can extract significant shape features that remain invariant under transformations like scaling and rotation. One of the main challenges in shape matching is the need for algorithms that can handle geometric transformations while maintaining accuracy. Traditional shape matching techniques, such as those based on Fourier descriptors or contour matching, often rely on pixel-based or feature-based representations. However, these methods can be sensitive to noise and variations in object orientation. In contrast, the common base triangle area approach focuses on intrinsic geometric properties, making it more resilient to such transformations. By analyzing the relationship between triangles in the shape’s contour, the method ensures that the matching process is both robust and computationally efficient. In this work, we introduce a method that first decomposes a given object into a set of base triangles by analyzing its contours. Each triangle is then characterized by its area, and the algorithm computes the common base triangle areas for pairs of triangles that share a common base. This process effectively captures the structural properties of the shape, allowing the algorithm to match shapes even in the presence of geometric distortions. The motivation behind this approach is to leverage the simplicity and computational efficiency of geometric primitives. By reducing the problem of shape matching to a comparison of triangle areas, we significantly simplify the computational complexity, making the method suitable for real-time applications. Moreover, this approach offers the advantage of being less sensitive to noise and minor deformations, which are common challenges real-world object recognition scenarios. The paper is organized as follows: In Section 2, we review related work in the field of shape matching object recognition, highlighting the strengths and weaknesses of existing approaches. Section 3 introduces the methodology behind the common base triangle area concept and the details of the proposed algorithm. Section 4 presents experimental results using several benchmark datasets, comparing the performance of the proposed method with that of traditional techniques. Finally, Section 5 concludes the paper with a discussion of the findings and suggestions for future research in the area of geometric shape recognition. This work contributes to the ongoing effort to develop efficient, scalable, and accurate methods for shape matching and object recognition, offering a promising alternative to more traditional approaches

2.LITERATURE SURVEY

Shape matching is a critical challenge in computer vision and image analysis, with applications ranging from object recognition to image retrieval and 3D reconstruction. Zhou et al. (2012) present an extensive review of shape matching techniques, exploring both traditional geometric methods and more contemporary approaches based on machine learning.

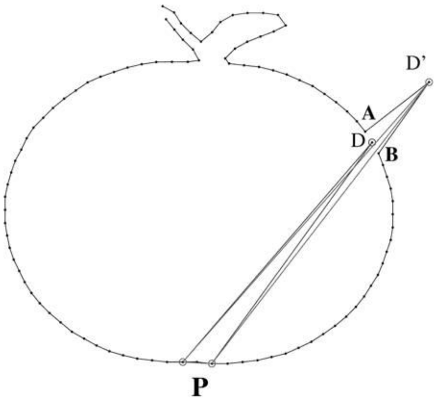

Fig 2. Splitting into triangles

The paper examines several algorithms for shape matching, focusing on their strengths, weaknesses, and the computational complexity involved [1]. Traditional methods, such as contour-based matching and Fourier descriptors, often struggle with variations in object shape, such as non-rigid transformations and partial occlusions [2]. In contrast, modern techniques, especially those based on machine learning and deep learning, show promise in addressing these issues by learning invariant features that can handle complex deformations and noise [3]. One key challenge highlighted in the paper is the need for algorithms that can perform robust shape matching in real-world scenarios where objects are often subject to noise, occlusion, and deformation. These challenges make shape matching particularly difficult in practical applications like robotic vision, autonomous driving, and medical image analysis [4]. The authors also discuss the various approaches used to handle these problems, such as the use of invariant descriptors, optimization techniques, and the application of learning algorithms to extract features that are more resilient to transformation [5]. Moreover, the paper addresses the problem of computational efficiency, as many of the existing shape matching algorithms can be computationally expensive, making them impractical for large-scale applications. One of the solutions proposed is the use of hierarchical approaches that progressively refine the matching process to reduce the computational load. The authors suggest that future work should focus on developing methods that can efficiently handle large datasets and perform real-time matching [7]. In conclusion, this paper offers a comprehensive review of shape matching techniques, highlighting the progress made in the field and identifying key areas for future research. The authors emphasize the need for more robust, scalable, and computationally efficient methods that can deal with the challenges posed by real-world data [6].

The problem of shape matching and object recognition has long been a central focus in computer vision. Unlike traditional shape matching methods, which rely on predefined geometric features, the shape context method captures the spatial relationships between points on a shape's contour, offering a more robust representation [8]. The key idea behind shape contexts is to use a set of spatial bins to discretize the distance and angle information between a point on the shape and other points in its neighbourhood [9]. These shape contexts are invariant to transformations like translation, scaling, and rotation, making them a powerful tool for shape matching. The authors propose a matching algorithm that compares the shape contexts of two objects and computes a similarity score between them. This matching approach can handle significant variations in shape, including partial occlusion and complex deformations, which are common challenges in real-world object recognition tasks. The algorithm is applied to several object recognition problems, such as recognizing human faces and various other shapes. Experimental results demonstrate that the shape context-based method outperforms traditional methods like Fourier descriptors and moment invariants, especially in terms of robustness to deformations and occlusions. In addition to object recognition, the paper also explores shape matching in the context of image retrieval. The authors show that by using shape contexts as a descriptor, it is possible to retrieve similar shapes from a large database of images, offering a more accurate solution compared to traditional image-based retrieval methods. The paper also discusses the computational complexity of the shape context method and proposes optimizations to improve its efficiency, such as using faster nearest-neighbor search algorithms and dimensionality reduction techniques.The authors conclude by emphasizing the importance of robust, invariant shape descriptors for object recognition and retrieval tasks. Moreover, the paper addresses the problem of computational efficiency, as many of the existing shape matching algorithms can be computationally expensive, making them impractical for large-scale applications [10]. They suggest that future work should focus on extending the shape context method to handle 3D shapes and dynamic objects, as well as incorporating learning algorithms to further improve performance.

3.SYSTEM DESIGN

The Block Diagram of our prototype is as shown below the main idea of the TAR method is to characterise the shape through a series of triangles whose vertexes are fixed and bases are changed.

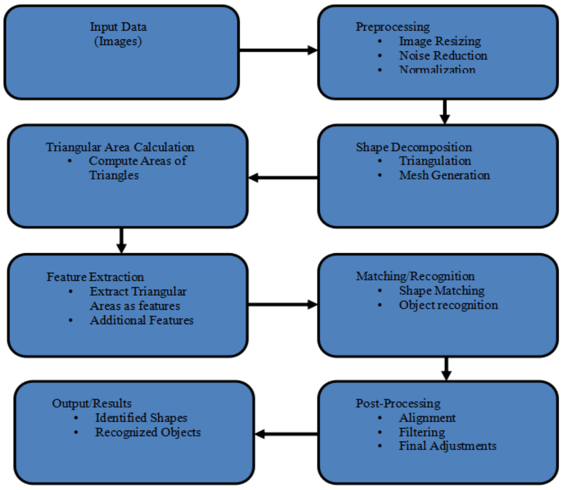

Fig 3. Block Diagram

This method can gain the multi-scale concave–convex information of contour points, whereas the spatial position information of some contour points is lost since the bases of the triangles do not change through them. In addition, the incessant changing process of the bases leads to increased computational complexity for extraction of shape features. In comparison with TAR, our method based on the defined CBTA is not only able to obtain concave–convex information on contour points, but also able to obtain the complete spatial position relationship information among all the contour points without spending time on obtaining multi-scale information . Since the contour of a shape is composed of a series of sample points, we start to describe the shape feature from each sample point on the contour (hereinafter referred to as a contour point).For this purpose, we define a new triangle to describe a contour point: the line segment formed by the two points next to this contour point as the fixed base of this triangle and all the contour points as the vertexes of this triangle. According to this definition ,a set of such triangles can be generated from a contour point p, as shown in Fig. 1. the incessant changing process of the bases leads to increased computational complexity for extraction of shape features. In comparison with TAR, our method based on the defined CBTA is not only able to obtain concave–convex information on contour points

Let S = {pi} (i = 1, …, n) denotes a uniformly sampled sequence of contour points in clockwise direction, as shown in Fig. 1b. The common base triangles for the point pi are constituted by the line segment pi−1pi+1 and each point pu (u = 1, …, n). Then, we use the areas of these triangles to measure the relative spatial relationship between the contour point pi and the point set {pu, u= 1, …, n}. Signed area of the triangle Δpupi−1pi + 1 is defined as

$$s_{i,u} = \frac{1}{2}\begin{vmatrix} x_{i-1} & y_{i-1} & 1 \\ x_u & y_u & 1 \\ x_{i+1} & y_{i+1} & 1 \end{vmatrix}, \quad u = 1, \ldots, n$$

where (xi−1, yi−1), (xu, yu) and (xi + 1, yi + 1) represent the planar coordinates of the contour points pi−1, pu and pi + 1, respectively. Then, we calculate all the areas of the common base triangles fo rpi as a shape feature vector called CBTA shape descriptor, which is defined as a column vector.

To analyse this novel descriptor, we draw the curves of the CBTA descriptors for the points at different positions on theButterfly-shape1 contour in Fig. 5a. From Fig. 5b–d, we can see that different positions of the points correspond to different CBTA curves, which indicate that the proposed descriptor has the ability to distinguish the relative position relationship of the contour points in one shape.

By comparing Fig. 5b with Fig.6, we find that the points at the similar position of a similar shape have the similar CBTA curves. In comparison with TAR, our method based on the defined CBTA is not only able to obtain concave–convex information on contour points, but also able to obtain the complete spatial position relationship information among all the contour points without spending time on obtaining multi-scale information.

$$S_i = (s_{i,i},\ s_{i,i+1},\ \ldots,\ s_{i,n},\ s_{i,1},\ s_{i,2},\ \ldots,\ s_{i,i-1})^{\mathrm{T}} \qquad (2)$$

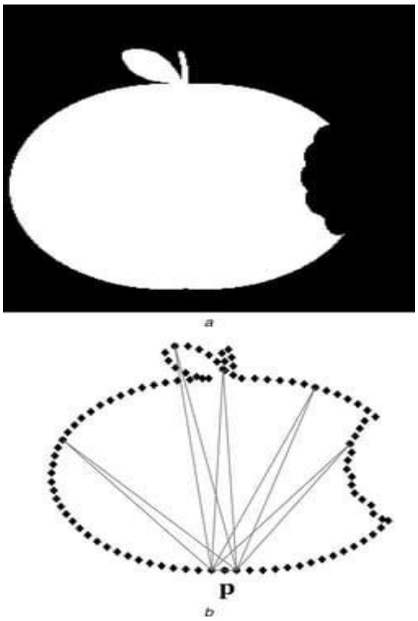

Fig 4. Binary Image of an apple

These analysis shows that the CBTA descriptor not only has a good ability to distinguish the positions of the contour points, but also can cluster their positions. According to (2), each point on the contour has an n-dimensional CBTA descriptor, so we can use an n × n matrix {Si} (i = 1, …, n) to describe the entire shape. On the other hand, we find that the first element si, i in Si characterises the concavity and convexity of points on the contour; that is to say, when the contour is sampled in a clockwise direction, positive, negative and zero values of si, I mean concave, convex and straight-line points, respectively. This is because si, i is calculated by the determinant of the points pi−1, pi and pi+1. The positive and negative of this determinant reflect the order of three points in a triangle and this order corresponds to the concavity and convexity of the points. Therefore, we define a vector cc, called concave–convex vector, as

$$cc = (s_{1,1},\ s_{2,2},\ \ldots,\ s_{n,n})^{\mathrm{T}} \tag{3}$$

The vector cc characterises the concavity and convexity of all the contour points. The curve of cc for a shape is shown in Fig. 4d.The amplitude of the curve corresponds to the concave and convex degrees of the contour, and 12 extrema on the curve mean12 significant corner points (four positive extrema mean four concavepoints on the contour and eight negative extrema mean eight convexpoints on the contour). However, the contour of this cross-shapedoes not consist of standard flat lines (as shown in Fig. 4b), whichmakes other non-zero values appear on the cc curve. However, it suggests that the proposed concave–convex vector can give much real characteristic of the natural image contour, which has important research significance in detecting the points whose concavity and convexity cannot be identified by human vision. The analysis above shows that the CBTA descriptor contains not only the relative position information, but also the concave and convex information of contour points in the shape, which indicates that CBTA is a comprehensive shape descriptor. On the other hand, the CBTA descriptor represents the relative (not absolute)geometrical position relationship among the contour points.

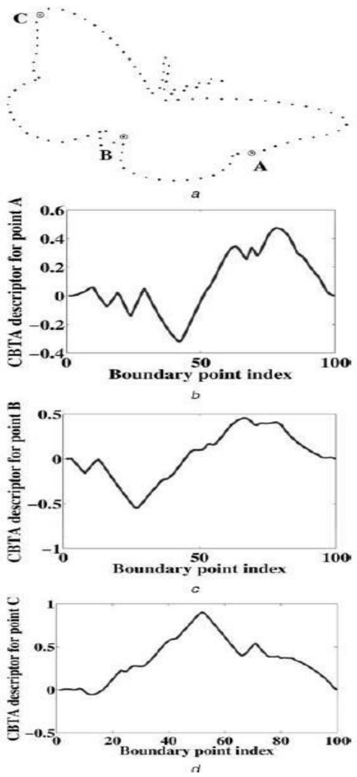

Fig. 5 CBTA curves for the contour points at different positions
a Contour point sequence of Butterfly-shape1
b CBTA curve for point A
c CBTA curve for point B
d CBTA curve for point C

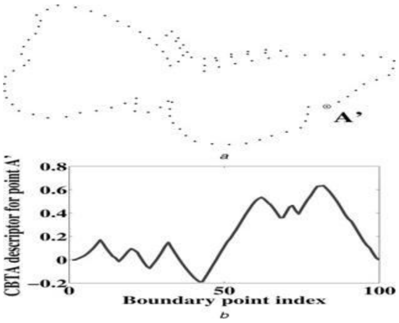

Fig.6 CBTA curve for the contour point at similar position
a Contour point sequence of Butterfly-shape 2
b CBTA curve for point A′

4.RESULT

The Kimia dataset is also widely used in shape matching and object recognition. It contains three sub-datasets: Kimia25, Kimia99 and Kimia216. In this paper, we choose the Kimia99 and Kimia216 datasets for retrieval test that are the most commonly used in shape matching, and all the shapes in these two datasets are shown in Figs. The Kimia99 dataset consists of 9 classes of objects with each class containing 11 shapes. Each shape from the Kimia99 dataset is used as a query, and the similarity of the rest of shapes to it is calculated. Then, we obtain the retrieval result by summarizing the number of top 1 to top 10 closest matches in the same class, and the best possible result for each of them is 99. The Kimia216 dataset consists of 18 classes of objects with each class containing 12 shapes. The retrieval method on the Kimia216 dataset is similar to the Kimia99 dataset. Results of our method on these two dataset are shown in Tables , respectively. To measure the retrieval rate of the algorithm on the Kimia99 and Kimia216 datasets more significant, elements of each row in Tables are summed and then the retrieval rate is obtained with this sum divided by the total number. We can see our method outperforms other methods. Particularly, we have also used the bulls eye performance (BEP) method to evaluate our CBTA descriptor. The BEP of the new histogram-based descriptor in is 97.43%, and the BEP of the CBTA descriptor is 96.69%, which is only lower than 97.43 by 0.74%.

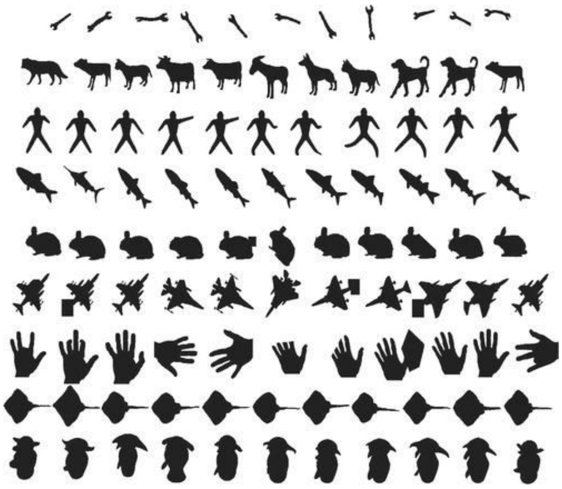

Fig. 7 Kimia99 dataset

Method	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Retrieval rate, %
SC	97	91	88	85	84	77	75	66	56	37	76.36
CPDH+EMD	96	94	94	87	88	82	80	70	62	55	81.61
general model	99	97	99	98	96	96	94	83	75	48	89.39
efficient indexing	99	97	98	96	97	97	96	91	83	75	93.84
path similarity	99	99	99	99	96	97	95	93	89	73	94.85
CBTA	99	99	99	99	98	98	97	95	95	75	96.36

5.CONCLUSION

In this paper ,we have proposed an over yet effective shape descriptor called CBTA for shape matching and object recognition on the basis of the spatial position relationship of contour points. The CBTA descriptor for each contour point is constructed using a set of triangles formed by its two neighbour points and other contour points, and then the areas of these triangles are used to represent the feature of it. A local smoothing process makes the CBTA descriptor more insensitive to noise and computationally efficient because of the dimension reduction. The DP algorithm gives the best correspondence of two shapes using the known order of the contour points. A fused retrieval framework, which is first proposed in this paper, efficiently improves the retrieval rate of the CBTA descriptor. The experiments on three popular data sets an excellent advantage on retrieval accuracy, robustness against noise ability and computation efficiency. We frankly recognise that our method does not perform well on the shapes containing complex interior information. Therefore, we will explore how to effectively extract the feature information of these shapes, and to enhance the recognition ability of the CBTA descriptor on these shapes.

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