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Efficient And Robust Shape Signatures For Object Recognition

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Abstract-

Content Based Image Retrieval (CBIR) is an important issue in the computer vision community. Both visual and textual descriptions are employed when the user formulates his queries. Shape feature is one of the most important visual features. The shape feature is essential as it corresponds to the region of interest in images. Consequently, the shape representation is fundamental. The shape comparisons must be compact and accurate, and must own properties of invariance to several geometric transformations such as translation, rotation and scaling, though the representation itself may be variant to rotation. This paper presents simple, efficient and shape descriptors for efficient image mining. The main strength of the method is its simplicity.

Keywords- Distance mapping, Image mining, Moment invariance, Object Recognition, Shape Descriptor, Shape Recognition, Shape signature.

I. INTRODUCTION

In recent years, content based image retrieval has been studied with more attention as huge amounts of image data accumulate in various fields, e.g., medical images, satellite images, art collections, commercial images and general photographs. Image databases are usually very big, and in most cases, the images are indexed only by keywords given by a human. Although keywords are the most useful in retrieving images that a user wants, sometimes the keyword approach is not sufficient. Instead, Query-by-example or pictorial-query approaches make the system return similar images to the example image given by a user. The example images can be a photograph, user-painted example, or line- drawing sketch.

Searching for images using shape features has attracted much attention. Shape representation and description is a difficult task. This is because when a 3-D real world object is projected onto a 2-D image plane, one dimension of object information is lost. As a result, the shape extracted from the image only partially represents the projected object. To make the problem even more complex, shape is often corrupted with noise, defects, arbitrary distortion and occlusion. There are many shape representation and description techniques in the literature.

This paper aims at addressing the CBIR challenges using only the shape signatures. This allows us to neglect the other information about the object, such as color and texture while retrieving the images, enabling us to use silhouette of the images instead of the images themselves. The paper proposes various shape signatures that help in achieving better recall rates & precision. The paper is arranged as follows: The next section provides the necessary background for CBIR. Section 3 deals with the shape descriptors under use and the performance of the present work are evaluated in section 4.The paper are concluded in section 5.

II. BACKGROUND

Shape analysis involves several important tasks, starting from image acquisition, reaching to shape classification. This section gives an overview of three major tasks of shape analysis problem:

1) Shape Description*:* Characterizes the shape and generates a shape descriptor vector (also called feature vector) from a given shape.

2) Shape Similarity*:* Establishes the criteria to allow objective measures of how much two shapes are similar to each other.

3) Shape Recognition: Labels the class to the input shape.

2.1 Shape Description:

The problem of shape analysis has been pursued by many authors, thus, resulting in a great amount of research. Recent review papers [6], [8] as well as books [2], [3] provide a good resource of references. In most of the studies, the terms shape representation and descriptions are used interchangeably. Since some of the representation methods are inherently used as shape descriptors, there is no well-defined separation between the shape representation and description. However, shape representation and description methods are defined in [1] as follows. Shape representation result in non-numeric values of the original shape. Shape description refers to the methods that result in a numeric values and is a step subsequent to shape representation. For the sake of simplicity, we consider the representation and description together throughout the section and refer them as shape description methods.

Shape description methods can be classified according to the use of shape boundary points or the interior of the shape: Region based methods and Boundary based methods.

1) Region Based Methods: Region based shape descriptors express pixel distribution within a 2-D object region. It describes a complex object consisting of multiple disconnected regions as well as a simple object with or without holes. Since it is based on the regional property of an object, the descriptor is insensitive to noise that may be introduced inevitably in the process of segmentation. Region based methods classified in [3] as follows: Moments, Angular Radial Transformation, Shape Decomposition, Shape Matrices and Vectors, Medial Axis Transform, Bounding Regions, Scalar Shape Descriptors.

2) Boundary Based Methods*:* Boundary based shape description methods exploit only objects boundary information. The shape properties of object boundary are crucial to human perception in judging shape similarity and recognition. Many authors, who study on the human visual perception system, agree on the significance of high curvature points of the shape boundary in visual perception. In the psychological experiments, it is suggested that corners have high information content and, for the purpose of shape description, corners are used as points of high curvature. Therefore, the shape boundary contains more information than the shape interior, in terms of perception. Boundary based methods classified in [3] as follows: Polygon Approximation, Scale Space Filtering, Stochastic Representation, Boundary Approximation, Set of Boundary Points, Fourier Descriptors, Coding, and Simple Boundary Functions.

2.2. Shape Similarity Measurements

Many pattern matching and recognition techniques are based on a similarity measures between patterns. A similarity measure is a function defined on pairs of patterns indicating the degree of resemblance between the patterns. It is possible that our prior knowledge of objects plays a significant role in our similarity judgments, a role which may vary considerably depending on the shapes we view. Since perceptual similarity is not a well-known phenomenon, none of the available similarity measures are fully consistent with the Human Visual System.

In this section, we list some desirable properties of similarity measures. Depending on the application, a property, which is useful in some cases, may be undesirable in some other cases. Combinations of properties may be contradictory. While some of the properties are satisfied by the distance function and the algorithm used in similarity calculation, the others are inherently satisfied by the shape representation. With the reference to [1], different similarity methods are Minkowsky Distance, Hausdorff Distance, Bottleneck Distance, Turning Function Distance, Frechet Distance, Nonlinear Elastic Matching Distance, and Reflection Distance.

2.3 Shape Recognition

Shape analysis systems extensively use the methodologies of pattern recognition, which assigns an unknown sample into a pre-defined class. With reference to [4], numerous techniques for pattern recognition can be investigated in four general approaches:

1. Template Matching,
2. Statistical Techniques,
3. Structural Techniques,
4. Neural Networks.

The above approaches are neither necessarily independent nor disjoint from each other. Occasionally, a recognition technique in one approach can also be considered to be a member of other approaches.

III. EFFICIENT AND ROBUST SHAPE DESCRIPTORS

Shape based image retrieval primarily involves three steps: shape descriptor, shape similarity measures and shape recognition.

3.1Shape Descriptor:

There are generally two types of shape representations: one is contour based and other is region based methods. Contour based method need extraction of boundary information which in some cases may not available. Region based methods, however, do not necessary rely on shape boundary information, but they do not reflect local features on shape. So in this experiment for generic purposes, both types of shape representation are necessary.

1) Scalar Shape Descriptor*:* The large number of scalar shape description techniques is presented by heuristic approaches, which yield acceptable results for description of simple shapes. A shape description method generates a shape descriptor feature vector from a given shape. The required properties of a shape description scheme are invariance to translation, scale and rotation. Scalar shape descriptor includes the following features like eccentricity and aspect ratio.

2) Simple Boundary Functions*:* The following descriptors are mostly based on geometric properties of the boundary. All of them are sensitive to image resolution. The following are some of the geometric descriptors like centroid distance and circularity.

3) Shape signature by level set method*:* The level set technique is a geometric deformable model implemented to segment a given image to extract the region of interest. The output of this technique is a distance mapped function wherein the boundary of the object is zero level set and other points are assigned signed distance from the boundary of the object segmented by level set techniques [10], [9], and [11].

The shape signatures are obtained from the distance mapped level set function. The number of points with different distance from the boundary can be a good shape signature. Here, number of pixels on the object boundary I_0, unit distance away from boundary I_1 and two distances away from boundary I_2 has unique relationship that depends on the shape of object. The normalize difference are computed by

$$r_{10} = \frac{I_0 - I_1}{I_0}$$

$$r_{20} = \frac{I_0 - I_2}{I_0}$$

$$r_{21} = \frac{I_1 - I_2}{I_1}$$

City block distance mapping is more suitable for this shape signature than Euclidean distances. This provides an additional advantage by reducing the computational complexity.

3.2 Shape similarity

The shape descriptors eccentricity, elongatedness, centroid distance, circularity, r_{10}, r_{20}, r_{21}, provides an excellent feature set in discriminative the shape of different classes. It provides a large distance between classes and at the same time maintains lower distances for objects belonging to same class.

3.3. Shape recognition

Shape of object has a strong connection to *image retrieval*, where the task is to retrieve a "matching" image from a (possibly large) database. The best match can then be determined after the objects present have been recognized.

1) Feature analysis and matching technique

The simplest way of shape recognition is based on matching the stored prototypes against the unknown shape to be recognized. General speaking, matching operations determines the degree of similarity between two vectors in the feature space. The set of features those represents a characteristic portion of a shape or a group of shapes is compared to the feature vector of the ideal shape class. The description that matches most "closely" according to the distance measure provides recognition.

3.4. Performance evolution:

Experiment deals with 16 classes of images in database each class containing 20 images. The experiment started considering only three features i.e., eccentricity, circularity and centric distance for the database. These features for the images in the database are computed and stored. The features of the query image are computed and the Euclidian distance to the mean of the features for each class is then computed. The query image is classified through Nearest Neighbor method. The retrieval rate was found to be poor i.e.60%. This low retrieval rate alarmed us about the inadequacy of feature set and 3 more features- aspect ratio, centroid distance & distance mapped signatures, were added.

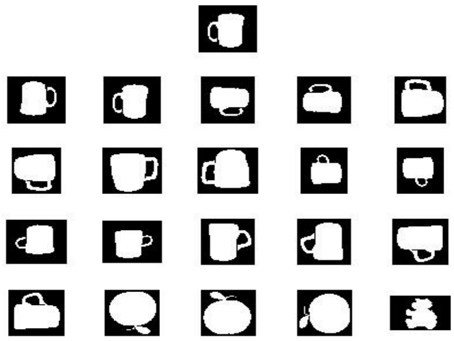

Fig1: Query: CUP

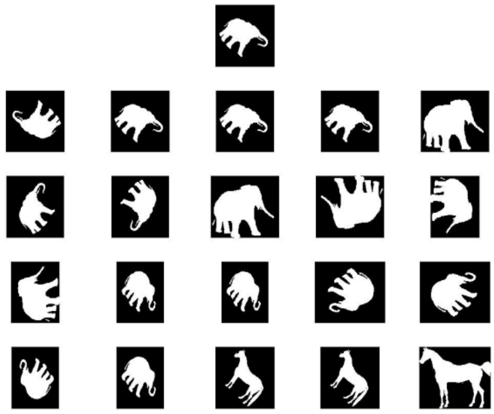

Fig2: Query: ELEPHANT

Some sample retrieved images are shown in figures 1 and 2. Here, in each set, the top image is the query image and top 20 retrieved images in the descending order of match are shown. The scale and rotation invariance of the retrieval can be easily observed. The mismatched shapes have some resemblances to the query image.

Many different measures for evaluating the performance of image retrieval systems have been proposed. The measures require a collection images in database and a query image. The common retrieval performance measures –precision and recall are used to evaluate.

1) Precision*:* Precision is the fraction of the shapes retrieved that are relevant to the users' requirements.

$$Pericision = \frac{No. of\ relavant\ shapes\ retrived}{Total\ No. of\ shapes\ retrived}$$

2) Recall*:* Recall is the fraction of the shapes that are relevant to the query that are successfully retrieved.

$$Recall = \frac{No. of\ relavant\ shapes\ retrived}{Total\ No. of\ relavant\ shapes\ in\ whole\ dat}$$

The overall performance of our method is measured in terms of Recall rate & Precision. The rigorous experiments are conducted to evaluate the performance. The table 1 shows the results of retrieving top 5, top 10, top 15 & top 20 shapes from the database. With all the features discussed, the retrieval rate has increased. From the table it can be seen that the monotonous decrease in precision with increase in no. of images retrieved indicates that the result are not accidental.

TABLE 1
Recall rates & Precision for various query shapes.

S.No	Input	Relevant				Total Relevant	Recall	Precision			
		Top-5	Top-10	Top-15	Top-20		R(20)	P(5)	P(10)	P(15)	P(20)
1	Apple	5	9	13	14	20	70%	100%	90%	87%	70%
2	Bat	5	10	13	15	20	75%	100%	100%	87%	75%
3	Bottle	5	10	15	17	20	85%	100%	100%	100%	85%
4	Car	5	10	15	17	20	85%	100%	100%	100%	85%
5	Child	5	8	12	14	20	70%	100%	80%	80%	70%
6	Cup	5	10	15	16	20	80%	100%	100%	100%	80%
7	Box	5	10	15	20	20	100%	100%	100%	100%	100%
8	Flower	5	10	13	13	20	65%	100%	100%	87%	65%
9	Elephant	5	10	15	17	20	85%	100%	100%	100%	85%
10	Horse	5	10	13	14	20	70%	100%	100%	87%	70%
11	Snail	5	10	12	12	20	60%	100%	100%	80%	60%
12	Teddy	5	10	13	15	20	75%	100%	100%	87%	75%
Average							76.6	100	97.5	91.5	76.6

IV. CONCLUSION & FUTURE WORK

Shape is one of the most valuable features to identify or describe objects represented in images. This paper presents a simple and efficient method based on a few set of image features to describe shapes. This method aims to be simple and to result in a short description.

Several improvements are intended to be carried as future work. A first one is to learn feature weights using, as for instance, evolutionary algorithms (e.g. genetic algorithms) to properly tune the used similarity distance metric. This process is expected to increase the accuracy of the classifier for a given dataset. These results can be also valuable for retrieval purposes if these weights demonstrate stability among several datasets.

Another improvement to the retrieval process is to make use of relevance feedback, where the user progressively refines the search results by marking images in the results as "relevant", "not relevant", or "neutral" to the search query, then repeating the search with the new information.

As a major conclusion we stand that our method demonstrated usefulness and effectiveness for both retrieval and recognition purpose, particularly if taken into account its simplicity.

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