A SCALE AND ROTATION INVARIANT FAST IMAGE MINING FOR SHAPES

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Abstract: In recent times, fast content – based image retrieval is required in image mining for shapes, as image database is rising exponentially in size with time. In this paper, a sample, fast and efficient process through Distance Mapping for CBIR is proposed. In distance mapped domain, zero valued points represent the boundary of the object and the rest are assigned the value with the shortest distance to the boundary of the object. All the regional points within the object are defined with positive distance while the background points are given negative distances. The shape signature proposed is obtained from the statistical properties of the distance mapped functional. The features used are the number of grid points within pre-specified narrow band region across the object boundary and their algebraic relationship. It is found that, these features are invariant to scaling and rotations. This increases the retrieval rate and also the speed of retrieval as no pre-scaling and rotation are required to register the shape. Conventional distance mapping is a time consuming process. This process can be used as coarse level in hierarchical CBIR that shrinks the database size from large set to a small one. This tiny database can further the database can be scrutinized meticulously using the above said methods like wavelets, curvelets etc. For feature extraction to improve the retrieval rate or even in the present work using accurate distance mapping.
Keywords: image retrieval, boundary, distance mapping, wavelets

1. INTRODUCTION

Image mining is one of the fast developing needs of today. It means to search for the images in the database that contain a particular object of interest. The current search engines use the file names for searching. The need of the day is to search the images that contain objects of particular shapes. The features used may be color, texture or the shape. Many methods are available in the literature to evaluate the color and texture of the object. But no fast method is available to compare the shape of an object while searching. This mooted work presents a fast method to identify the signatures of the shapes. And these signatures can be used to mine the shapes from the given set of images.

The signature for the shapes is derived from the distance mapped functional. Here the points that are on the boundary of the object are assigned zero values (11). The other points are assigned the value that is lesser distance between the current point and the boundary of the object. The literature presents many ways of distance mapping. But these methods are highly time consuming. This paper uses a new novel method called ‘Distance mapping by Scanning and Filling Technique’, DSFT, which produces the city-block distances in the shortest time.

The shape signature is obtained from the distance mapped functional. The relationship between the numbers of points having values zero, one and two is the main feature used to distinguish between different shapes.

2. BACKGROUND

Shape representation and recognition is one of the important steps in object recognition. One of the earliest works on shape representation is the Hough transform that is defined to represent straight lines, circles and ellipses [1,3,9,12,18,19]. This was first introduced by Paul Hough in 1962. Many authors have contributed in improving the method and also extended to detect circles, ellipses etc [1, 3, 9, 12, 18, 19]. The ellipse detection through Hough-like method is computationally very expensive both in time and space domains. In this regard, Daul et. Al. [6] suggested a new approach that rotates and scales an ellipse to fit into a circle. But due to implicit
large combination of rotations and scaling factors to generate a best fit combination that yields a circle, $O(n^3)$ order of computation is required.

To reduce the time complexity, we have introduced an efficient method that detects an ellipse in linear time $O(n)$ [16]. This method computes the intersection points of the lines normal to the curve and depending on the pattern of these intersection points one can surmise the given feature as a circle, an ellipse or an irregular shape. For the objects with no regular shape, one can use the curvature along the curve as a feature to represent the shape. Here the curve is parameterized $s \in [0,1]$ and the curvature $\kappa(s)$ is measured along the curve and this data is used as the shape signature. This is a modified version of Curvature Scale Space (CSS) image matching [13]. The idea is to calculate the curvature along the curve and note the curvature zero crossings. Then the curve is evolved using Gaussian smoothing and the curvature is computed at the varying levels of detail and the curvature zero crossings are noted at every level. With smoothing, the number of zero crossing points decreases. This decrease during evolution is found to be unique for each shape and hence is suggested by the authors as the shape signature. This method, though robust wrt noise and transformation like rotation and scaling, suffers from a disadvantage that it is computationally intensive as the curvature is to be computed at every point along the curve at every level of detail. Hence it has a very high time complexity $O(n^2)$ and space complexity $O(n^2)$. Cheikh et. al. [5] have proposed a boundary-model approach to estimate the shape match based on ordinal correlation. This method operates in 3 steps: object alignment, contour to multilevel image transformation and similarity evaluation. To approximation the similarity between two shapes, the boundaries are first aligned such that the major and the minor axes of each shape are oriented in a standard way for all the shape boundaries.

The binary images containing the boundaries are then transformed into multilevel images. One way to transform is using the distance mapping. Then the ordinal measure approximations the similarity between the two shapes based on the correlation of their corresponding transform images. Here the images are again sized to a common size and then divided into a fixed number of regions and each block in one image is compared to the corresponding block in the other image in an ordinal fashion. This method too is computationally expensive as it requires the images to be aligned before comparison and involves time consuming ordinal measure estimations.
Cremers and Soatto [7] have proposed a method integrating earlier shape knowledge into level set based segmentation methods. They used a dissimilarity measure that constitutes a pseudo-distance. This measure is symmetric and not biased toward small area. Here the distance mapped functional of the prior is integrated with the level set curve evolution. The reference distance mapped functional is translated, rotated or scaled once in each iteration of curve evolution and tried to fit with the shape in the image to be segmented. This method can be used to reconstruct the missing parts or can be used to find the objects in the image of the shape even if the object is occluded.

Raviv et. al. [15] also proposed a similar technique that recognizes the object of a given shape even with perspective distortion. This technique use Chan-Vese level set framework that is used with shape-similarity measure and embeds the projective homography between prior shape and the image to segment with a region-based segmentation functional.

The above techniques can recognize the given shape in the image even with occlusion and perspective distortions. However, these are highly time consuming as they are integrated with the curve evolution using level set method that add to the time complexity at every iteration of curve evolution. Hence they are not suitable directly for shape mining from a large database. We propose a method that uses the statistical moments of the distance mapped functional for shape registration and recognition. Here the level set method is used to extract the boundary of the object. Since this method is used only once to derive the shape features of the object in the image, it is not a highly time consuming process as opposed to those explained earlier. This method is suitable for initial shape mining and the results of our method, on a small set of images, may be subjected to more detailed registration and recognition phase using the above two techniques.

3. PROPOSED METHOD:

The method proposed makes use of the distance mapped functional as the input while comparing two shapes. The idea is to use the statistical features of this distance map to differentiate between different shapes. There are quite many techniques available to distance map. A distance map is a functional in which the value at each pixel is its minimum distance to the set of object pixels O in the original image:

\[ D(p) = \min\{dist(p, q), q \in O\}. \]  
\[ D_e = \sqrt{(p - q)^2} \]
The Euclidean distance is an accurate but highly time consuming metric, \(O(n^3)\). This stimulated the users to construct several alternative algorithms. They are characterized by masks swept above the domain in multiphase manner. These distances commonly initiate in literature are city-block, chess-board distances, to name a few. These are not as accurate as the Euclidean distance, but are computationally fast. Borgefors [4] developed a method for distance transformation in random dimensions. This method scans the area twice, once in the forward direction and then in the backward direction and the distance is calculated by either city-block or chess-board etc. mask through convolution. The convolution process limits the computational speed. Cuisenaire et. al. [8] mooted different approaches to calculate an estimated Euclidean distance using an ordered propagation by bucket sorting. This process too is computation extensive and hence has a limited speed. Jang et. al. [10] came up with undisturbed version of Euclidean distance mapping, called the pseudo distance mapping that computes the distances via Partial Differential Equation (PDE). This infers the in-built existence of time consuming computation. Ragnemalm [14] mooted a distance mapping method that uses well-ordered propagation instead of simple scans. It too appears to possess computational burden.

This paper uses a novel technique, called Distance mapping by Scanning and Filling Technique, (DSFT) [17]. This technique involves only scanning and counting but no convolution. Hence it is very fast. Its result is a city-block distance mapping. The time to map the distances is invariant of the size of the set \(O\) and depends only on the size of the canvas as opposed to the Euclidean distance mapping that grows exponentially with the size of the set \(O\). The proposed method for shape matching derives the shape features from the distance mapped functional. Here the points on the boundary of the object are assigned zero values. The other points are assigned the value that is the shortest distance between the current point and the boundary of the object. To differentiate between the regions inside from that outside the object, the distances outside the object are given negative values. The shape features are derived from this distance mapped functional. The features used are the number of grid points within a prescribed narrow-band region across the object boundary and their algebraic relations in the normalized sense.
The image mining process consists of two phases: the learning phase and the searching phase. In the learning phase, the features of the shape are computed for each object in each image in the database and the feature database is built. In the scanning phase, the features of the test object are computed and these features are compared with those in the feature database for the nearest match. The distance metric used to find the match can be Euclidean, city-block or chess-board. In the learning phase, the object is segmented using level set method and the object boundary information is used to generate the distance mapped functional. The shape features are derived from this distance mapped functional. The features are the number of points on the object boundary, the number of points in the narrowband around the boundary and their normalized algebraic relations. Hence the proposed method is invariant to scale and orientation. This makes the method more robust as it can match the shapes of the objects irrespective of the scaling and rotation of the object in the images.

4. RESULTS & DISCUSSION

We have tested the proposed algorithm on several images containing various types of shapes. The distance metric used here is the city-block to reduce the computational cost. It is also observed that the results are almost same as that obtained with the costly Euclidean metric. The boundaries are extracted through level sets method. This gives us an advantage over other methods of boundary extraction that the information provided by this method is the boundary as a signed distance function. This information is directly used in computing the shape features. The narrow-band of width of two pixels is used. Figures 2 to 4 show the results of the proposed method for image mining.
**5. CONCLUSIONS AND FUTURE SCOPE**

In this paper, we have shown a fast and simple method of finding the shape features using the distance mapped functional. The main objective presented in this paper is to seek alternative to speed up the mining process. As far as the matching is concerned, other distance metrics may also be used. Further, a research is in growth to improve the method aiming to increase the retrieval rate.
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