Object Identification Using Raster Models: A Comparative Analysis

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Abstract

Shape is most important visual feature of an image. Most of the region based shape descriptors are complex in nature and computationally intensive. In this paper, we analyzed various raster models like circular, square by exploring exterior contour information with the help of grid based approaches. Spiral models are introduced in this paper with a comparative study. We compute a one dimensional shape vector from two dimensional shape region. The retrieval performance of these raster models are evaluated over 400 test images.

Keywords: *shape description, shape vector, spiral raster, object identification*

1. Introduction

Cyber space utilization is mounting at a splendid rate with an enormous amount of information prevailed in the form of text, images and videos. Exploration is an important criteria to extract meaningful content from the human perspective. One of the important approaches of the present day solutions is associated with metadata, which is used to describe image and video information. However, it is difficult to express multidimensional information of image through metadata. While handling this issue, content based image retrieval is evolved as an important active research area. In many cases, information is domain specific in the fields like designing, diagnosis, verification, simulation and modeling. In this context, it is difficult to retrieve the relevant image and video information. In this process, extraction of the content based visual features is a challenging task.
Machine based recognition is a much more difficult task due to the limitations of algorithms that is in vague. Out of a large set of features, shape is one of the important visual features for classification and in certain cases for retrieval also. Close resemblance with human perceptual content is the primary requirement while describing shape information of the object embedded in image or video. The accuracy of the image retrieval system depends on shape descriptors efficiency and their effectiveness.

2. Related work

In any image, shape is a low level perceptual feature mostly related to the spatial arrangement of an object. Shape representation [1] can be broadly classified into contour based and region based methods. Boundary lines are adopted to represent external shape information in contour based methods. Whereas, region represents the correlation features among pixels in detail, which can be adopted as a reflective measure of shape. It is necessary to model the two dimensional and three dimensional information of region, while representing the shape. In this process, contour based methods transform two dimensional regions into a one-dimensional vector while reducing the computational complexity. As per MPEG standards low computational requirement is one of the six features of the descriptor. Simple shape representation methods of region based approaches adopt grid samples [2] to obtain shape vector.

Shape description reflects dominant and intuitive features based on shape interior and exterior information. Features like signature, histogram, moments, curvature, shape context, shape matrix, spectral components are some special and transformed vectors, useful for machine based algorithms. The evaluation of shape descriptor not only depends on accuracy but also on the amount of information content of the object. In fact MPEG-7 stated several qualities to measure a shape descriptor, that is, good efficiency, compactness, effectiveness, complexity, robust and hierarchical coarse. Efficiency of shape descriptor indicates the capability to retrieve images from a stored set of images intuitively similar. The specific nature of retrieving distorted images is based on the compactness [3] of descriptor. In general, a descriptor should be capable enough in describing the shape information of all types of objects. However, practical conditions limit the boundaries. Complexity indicates descriptor clarity and stability in computation processes. Hierarchical coarse indicates descriptor priorities while retrieving similar images. Region based descriptor uses both exterior contour and interior pixel information of shape. Further, it can be applicable to non-connected and disjoint shapes also, but not to emphasize contour feature which are perceptional. Conventional descriptor uses polar sampling [4] which is simple and one-dimensional. Polar raster sampling uses border method for region based shape description.

Hu attempted [5] invariant geometric moments which are useful for image recognition and other applications. Limitations are observed with lower order moments as they are not adequate in recognizing shapes accurately. Complexity increases with higher order moments. However Zhang and Lu found [6] that geometric moments performed well for similar and finely transformed shapes of MPEG_7 database. Later Tau bin and Cooper computed algebraic moments [7] from first m central moments in the form of Eigen values of predefined matrices.

Teh and Chin studied [8] some of the orthogonal moments like Legendre, Zernike and pseudo Zernike moments and non-Orthogonal moments: geometric moments, complex moments and rotation moments for description of shapes in their retrieval process. Zernike moments and pseudo-Zernike moments are described more accurately than Legendre moments for distorted and normal images. Compared to the above, Zernike moments are found [8] to be more promising shape descriptors and are popular as region based features. To avoid complex computations and inconsistency in radial and circular features captured by Zernike moments, Zhang and Lu proposed [9] Generic Fourier descriptor (GFD). The GFD is computed by using Fourier transform of polar samples obtained from shape. When compared to Zernike moments, GFD is simple and accurate due its multi resolution analysis. Lu and Sajjanha introduced [10] grid sampling, in which a grid of cells laid on a shape. Grid is then scanned row wise and columns wise. Coverage of cell is represented as true, else it is false, results into a bit map. This approach is simple and computationally less complex. The similarity between shapes is measured in terms of Hamming distance.

By adding adaptive resolution Chakrabarti et al. improved [11] grid sampling descriptor. Grid descriptor is simple in representation but unreliable and noise sensitive. Goshtasby proposed [12] shape matrix which is derived from a circular raster sampling technique. Shape matrix representation is invariant to variations of a shape. To ensure uniform sampling density Taza and Suen [13] added weighted shape matrix. Shape matrix is sensitive to noise and expensive in shape matching. Puriet. al introduced [14] relative areas of shapes contained in concentric circles laid on a shape. Zhang and Chun Li developed [15] one dimensional representation of region based shape vector called as raster based polar sampling (PRS) signature. In this method a polar raster circular grid is overlaid on the shape. Computation is carried out on the number of shape pixels on each of concentric circles. These one dimension signatures vary as functions of radius and angle.

3. Raster models for shape description

In a grid based approach, raster will be selected while defining interior region of the object which is further transformed into shape vector. The basic principle in this approach is associated with the area covered by the object while representing region. However, the same principle can be extended to identify the exterior information of the object. In this approach, the number of boundary points that are present in any selected region of the grid will provide the information associated with object boundary. The normalized vector derived from this approach can be defined as shape vector. In the present work, we evaluated three raster models viz circular, square and spiral models.

3.1 Circular Raster

The circular raster model consists of concentric circles and radial lines. Circles are segmented into subdivided regions with the help of radial lines. The sub regions can be uniform or non-uniform portions based on the specific definition. The raster radius is selected as maximum of all distances computed between centroid and boundary point of shape, such that it covers shape completely which is denoted as Rr. The radii of internal circles are computed as rcon=Rr/N where N is number internal circles. The centroid of the shape is computed using boundary coordinates of shape as given in equation (1), which is applicable to the raster models presented in this paper.

$$xc = \frac{1}{n}\sum_{i=1}^{n} x\mathrm{b}$$
$$yc = \frac{1}{n}\sum_{i=1}^{n} y\mathrm{b} \quad \ldots\ldots..(1)$$

Where (xi,yi) indicates boundary points of shape and n is the number of boundary points.

In shape description, this raster is laid over the shape such that center of raster coincides with centroid of the shape. The number of shape pixels on each circle is counted as samples and the number pixels corresponding to circle radius stored

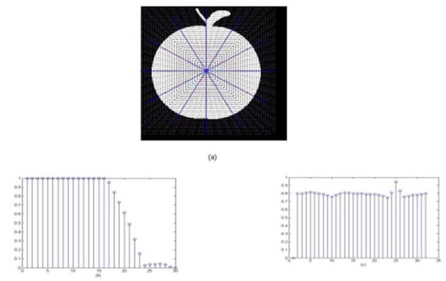


Figure.2 Square raster model a) raster over object, b) radial shape vector, c)Angular shape vector

as a vector. This vector represents radial information of the shape. Sampling density is more at interior circles when compared to outer circles. To overcome this problem, the vector is normalized with total number of points on each circle of raster. The resultant is a normalized radial vector as shown in Figure.1. Similarly, along the radial lines shape pixels are computed at regular samples. All radial lines are equal in length and numbers of lines depend on angle between radial lines. The number of shape pixels against radial lines are presented as a vector called Angular Vector. The angular vector can also be normalized with respect to number of pixels on a radial line.

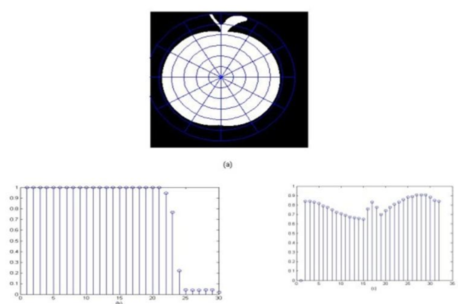


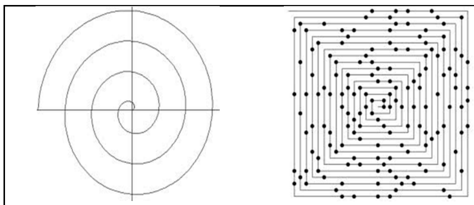
Figure.1 Circular raster model a) raster over object, b) Radial shape vector, c)Angular shape vector

3.2 Square Raster

Square raster model consists of concentric squares and radial lines. The radial lines length is equal to maximum of distances calculated between centroid and boundary points of shape. The maximum radius is divided into ' n' equal parts and n squares are included in raster with side length equal to double the radius. In this model, shape description raster is placed on the shape such that center of raster coincides with centroid of the shape. The number of shape pixels on each square circumference are counted and considered as sampled vector against the square side. To avoid size dependence in sampling, the radial vector is normalized using total number of samples on each square circumference and shown in figure 2. Like in circular raster, the radial vector for square model is calculated and normalized. The resultant angular vector is shown in Figure.2(c)

3.3 Spiral Raster

In this section, two spiral raster models are proposed. The Archimedean spiral has the property that any ray from the origin intersects successive turnings of the spiral in points with a constant separation distance and it is similar to circular raster. The spiral radius r, as presented in Figure. 3 (a), in polar coordinates(r, θ) can be described by the equation $r=a+b\theta$, where a and b real numbers. Changing the parameter *a* will rotate the spiral, while *b* controls the distance between successive turnings. The radius is not constant as in circular, two radial vectors are introduced. Ulam Spiral or Prime Spiral which is also having constant spacing between turns is shown in Figure 3(b), constructed by writing down a regular rectangular grid.



(a) (b)

Figure. 3. Spiral Raster Models a) Archimedean Spiral, b) Ulam Spiral

3.3.1 Complete Cycle Radial Vector of Archimedean spiral

Arithmetic Spiral raster is laid over the shape such that its center coincide with shape's centroid and the size of spiral covers the shape completely. As in spiral, the radius is not constant. We consider one complete cycle i.e. 360 degrees, on spiral. To cover the complete shape, numbers of successive cycles are considered along spiral from origin, from the centroid of the shape. For each cycle the number of shape pixels are computed, represented as a radial vector against the number of cycles. The radial vector is normalized with respect to total pixels on the cycle. The angular vector is computed as number of shape pixels on radial lines. The angular vector is normalized with total number samples on radial line. The raster model and vectors are shown in Figure.4

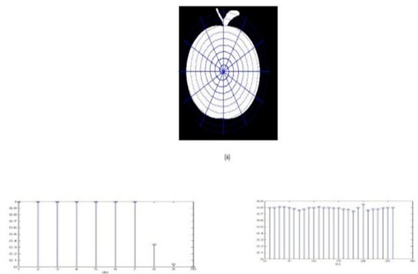


Figure.4 Archimedean spiral model complete cycle radial vector a) raster over object, b) Radial shape vector, c)Angular shape vector.

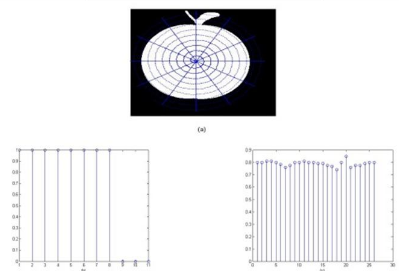


Figure 5 Archimedean spiral model fixed angle radial vector a) raster over object, b) boundary of object, c)Radial shape

3.3.2 Fixed Angle Radial Vector of Archimedean Spiral

In fixed angle method the spiral raster is divided with radial lines at a fixed angle and the numbers of pixels on each spiral segments between two radial arms are computed. We repeat this for all segments, for remaining radial lines till full cycle is completed on spiral. The number of shape pixels form radial vector in this method is used for identification. In the above methods, radial lines are fixed and invariable with angle and radius. The numbers of shape pixels on each radial line represent angular vectors. The radial and angular vectors for the above method for an object image are shown in Figure 5.

3.4 Ulam Spiral Raster

In Ulam spiral the distance between consecutive cycles is constant and each cycle of spiral form a square. In this method the radial vectors are computed as the number shape pixels on one complete cycle of spiral. One square cycle of spiral is considered as one cycle**.** The angular vectors are computed as number shape pixels on each radial line at a fixed angle. The Ulam spiral raster radial vector and angular vectors of an image are shown in Figure.6

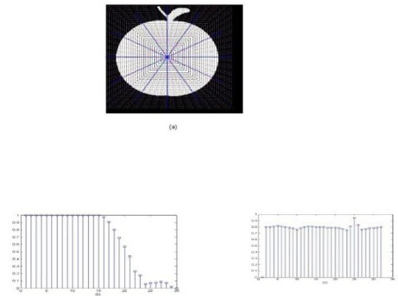


Figure 6 Ulam spiral model a) raster over object, b)Radial shape vector, c)Angular shape vector

4. Performance Evaluation

We tested the performance of five raster techniques using a database derived from MPEG-7 part A consists 400 shapes of 20 and in each category having 20 object images. This database includes scaled images, rotated images and modified images. The object image set is presented in Figure 7.

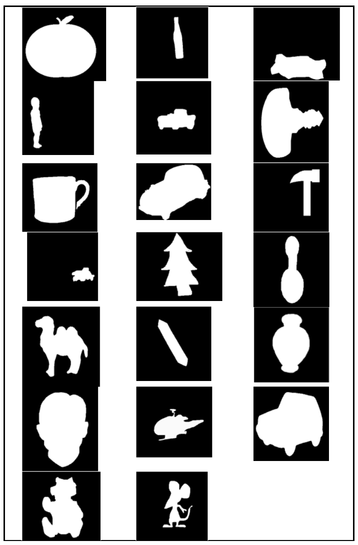


Figure 7. Object images set

For all images in the database we generate radial shape vector using circular raster model. Generalized object shape vector is computed by averaging radial shape vectors of all 20 images of the respective object, which denotes the basic shape vector. In this way for all objects basic vectors are generated and maintained as a basic vector table. Similarly, approach is adopted while generating basic shape vector for each raster model. While testing the retrieval performance of the raster model, we consider a test image in the object database and computed radial shape vector of the respective image. This vector is tested with the help of Euclidean distance in comparison with the basic shape vectors of all objects of the corresponding raster. The minimal Euclidean distance corresponds to similar object. Physical verification is carried out whether the test case is successful or not. In this way retrieval efficiency of the raster model is computed for a range of test images varying from 20 to120 with an addition of 20 images for each test set. The retrieval efficiency of all raster models presented in table1. Apart from considering the single minima, we extended our experiment by considering 2nd and 3rd minima also. The evaluated results are presented in Table 2.

Table 1: Retrieval efficiency of Raster models (First minima)

Name of the raster model	Retrieval efficiency (%) (For given number test images)					
	20	40	60	80	100	120
Circular Raster model	50	52	55	59	56	56
Square raster model	45	45	42	45	43	43
Arithmetic Spiral model with full cycle	60	57	60	61	60	60
Arithmetic Spiral Model with fixed angle	47	50	50	50	49	50
Ulam spiral raster model	55	50	48	48	48	46

Retrieval efficiency is observed to be consistent around 80% for Arithmetic spiral model with fixed angle in case of first minima. Highest efficiency is observed with Arithmetic spiral model with full cycle in both the cases. Square raster model is found to be relative inefficient when compared to other models. For a test set of 100 and above the retrieval efficiency are observed to be consistent in all cases. In case of circular and square raster models there is a significant increase in retrieval efficiency with increase in number of minims while adopting Euclidean distance comparison. However, the rate models are found with a limitation of around 80% retrieval efficiency in all cases.

Table 2: Retrieval efficiency of Raster Models For three minima

Name of raster model	Retrieval efficiency (%) (For given number test images)					
	20	40	60	80	10 0	120
Circular Raster model	75	80	77	77	77	77
Square raster model	70	67	67	69	68	66
Arithmetic Spiral Model(with full cycle)	75	80	83	81	82	83
Arithmetic Spiral Model (with fixed angle)	73	71	75	78	76	76
Ulam spiral raster model	75	75	76	77	75	72

5. Conclusions

In this paper, we introduced spiral models for describing shape information of an object in any image. We slightly modified grid models by considering the number of boundary points in a predefined region resulting into a shape vector. The normalized shape vectors of an object are computed and then transformed into a basic shape vector of respective image. This vector formulated the basis for representing the shape information of corresponding object using Euclidean distance measure we try to extract similar object from the object data base representing the test image. The performance analysis is carried out on all raster models with an observation of significant improvement using arithmetic spiral model with full cycle. The raster models are observed with a maximum efficiency of 80% only. However, angular shape vector is another feature that can be added with radial shape vector while evaluating the performance of raster models, which is in progress.

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