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A Review: Shape Based Image Retrieval

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Abstract— Most of the research advancements are motivated by market forces or changing customer demands. The demand for effective image retrieval system has been increasing due to massive expansion in volume of digital images on World Wide Web. The necessity to explore huge amount of online multimedia has become a prime reason for boosting development of efficient content based image retrieval algorithms. This paper mainly concentrates on low-level visual features of digital images especially shape features which have been able to reduce the semantic gap between human visual perception and retrieval system's ability to extract distinct features from image for effective similarity matching. A comprehensive review of recent advancements in shape based image retrieval is presented here, considering different shape features employed by different content based image retrieval systems as focus of study. An outcome of this study is leveraged as a comparative analysis based various computational parameters. This can pose challenges for the researchers and gives directions for future enhancements.

Keywords— Content-based image retrieval, Review, Semantic gap, Shape features, Shape matching, Shape representation.

I. INTRODUCTION

In the digital era of human life, multimedia has become a key conveyor of carrying information of diverse forms. Due to wide use of digital devices like smart phones, cameras, more and more images are produced and uploaded by netizens on the internet for business promotions, community sharing and many purposes. According to Annual Internet Trends Report [1], enormous amount of multimedia content is shared by internet-connected people on visual social media sites such as Snapchat, Instagram, Facebook and WhatsApp etc. The driving force of connectivity has made netizens upload and share billions of photos per day to socialize their presence on huge platform. Huge volume of images laid challenges for an effective image retrieval system.

Image retrieval systems are classified into two categorizes – Text based and Content based. Text-based image retrieval approaches [2] use keywords to describe content of image but it is insufficient to describe the content of image. This concern arises due to difficulty in describing an image with exact words and phrases. Also text-based image retrieval systems are linguistic which limits their usage to specific languages only. An effective image retrieval system needs to address insufficiency concern. As content of image is much distinct and relevant than showcasing the image with annotated keywords, Content Based Image Retrieval (CBIR) has emerged as an effective alternative to text-based image retrieval approach. The underlying assumption of CBIR system is that a sufficient amount of information is present in an image itself to generate unique description; it means image itself preserves its own identity. In content based image retrieval system low level visual features of an image are considered more comprehensive than high level features. As higher retrieval accuracy can be achieved with low level visual features.

Content-based image retrieval captures distinct visual information of an image based on its color, shape, texture and spatial layout to generate its unique identity. A representative content-based image retrieval system is as shown in Fig.1. A system comprises of two stages: offline and online stage. In an offline stage, distinct visual features of the images in repository are extracted and described by the invariant feature vectors. These feature vectors build feature database which ultimately produces an index structure for feature. In an online stage system user provides query image for obtaining relevant images. System then extracts distinct features and generates invariant feature description for query image. Next similarity measure is used for identifying possible relevant images and finally images are retrieved with the help of efficient indexing scheme to get relevant and true matches.

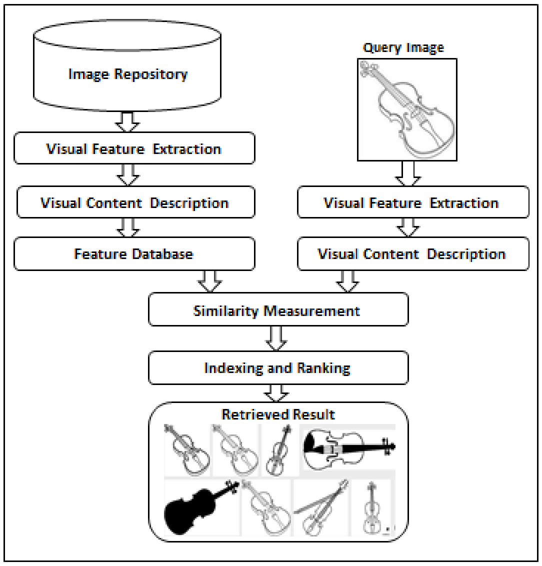

Figure 1. Representative model of content based image retrieval system

Content based image retrieval has a vast number of applications in numerous fields; some of these are listed below,

- Intellectual Property Management: Intellectual property rights such as copyrights, trademark and industrial design should be preserved from unlawful usage. In order to protect these intellectual rights, CBIR systems are used in intellectual rights registration and verification procedures to assist for searching whether newly registered property right imitates any of the existing intellectual property right.

- Medical Diagnosis: Medical practitioners generate repository of x-rays and ultrasound images in the digital form. These images can be retrieved with CBIR in future for clinical decision making. This enables faster diagnosis and facilitates appropriate treatment.

- Art and Design: This field comprises of architecture, fashion and graphic design, publishing and advertising etc. In this field one can have a repository of designs and photographs for future use. The designs can be made better in comparison with preserved images by searching for relevant images.

- Criminal Investigation: Criminal evidences in the form of fingerprint, shoe impression, face and surveillance recordings need thorough analysis. For which CBIR system gives effective tracking mechanism and helps in finding relevant evidences.

Other areas include online shopping, legacy films and video archives, military applications, remote sensing, tourism, space exploration, product manufacturing etc.

The paper is organized as follows. Overview of different visual features used for content based image retrieval and several surveys are presented in Section II. Section III focuses on categorization of shape based features. Datasets used by different CBIR system are given in Section IV. Section V presents comparative study of different methods based on important parameters. Section VI presents challenges and future research directions.

II. Overview Of Visual Features

Feature extraction is an essential component of content-based image retrieval system. In broader perspective, features are of two types, low-level visual features -which capture minute changes in visual information of the image and high-level features -which are used to correlate the image with annotated keywords. The common variants of low level features are, i) Photometric features: derived using color and texture information from raw pixels ii) Geometric features: derived from object shape in an image.

a) Color: Color is a visual perceptive property in human beings and animals in order to identify and describe an object. As per the literature survey [3, 4] several existing CBIR systems use color features. Initially color space is stated and then color features are extracted using different methods. Most commonly used methods are color histogram, color moments, color coherence vector etc.

b) Texture: Texture is an important parameter in image retrieval. It provides depth and orientation of an object. Texture can be regular having repetition of pattern (e.g. bricks) or irregular with no repeated pattern (e.g. cloud, sea). Texture analysis can be carried in three different domains spatial (statistical), structural and spectral. Texture features such as contrast, uniformity, coarseness, roughness, regularity, frequency, density and directionality can be used for identifying contents of an image.

c) Shape: Shape is one of the primitive level features of image, as there are substantial evidences that natural objects are identified by their shape. Shape as compared to other features like texture and color is more effective in representing the content of an image. Since human visual perception and the way of judging an objects are heavily relied upon shape characteristics; shape features have emerged as an effective way of representing an image in an image retrieval system.

The importance and popularity of shape based image retrieval has led to several surveys, comparative and experimental papers which are listed in Table I chronologically. Each paper listed has covered only a subset of the feature descriptors in shape based image retrieval.

Table 1: Survey on Shape Based Image Retrieval

Year	Reference	Topic
2000	[5]	Fourier Descriptors with Different Shape Signatures
2002	[6]	Comparison of Region Shape Descriptors
2003	[7]	Evaluation of MPEG-7 descriptors with different shape descriptors
2003	[8]	Evaluation of distance metrics
2004	[9]	Review of shape representation and description techniques
2007	[10]	Comparison of Boundary based methods
2011	[11]	Evaluated shape descriptors.
2011	[12]	Performance of individual and hybrid shape descriptors.

D. Zhang [5] has compared Fourier descriptors derived from different shape signatures and concluded that these signatures have substantial effect on retrieval results. D. Zhang and Guojun Lu [6] exclusively surveyed region based feature descriptors and evaluated performance based on six standard MPEG-7 parameters. In paper [7] D. Zhang has evaluated standard MPEG-7 adopted descriptors with different shape based descriptors. D. Zhang et al.[8] has given a good review of different distance metrics for shape based image retrieval. In paper [9] D. Zhang et al presented a detailed review of existing techniques for representation of shape descriptors. They stated implementation process and discussed merits and demerits of enlisted techniques. Cyrus Shahabi et al.[10] emphasized on different shape based descriptors but performance evaluation is confined to the boundary based methods. A. Amanatiadis et al.[11] analyzed in detail few contour based and boundary based methods considering computational complexity, number of coefficients required and retrieval rate. S.Selvarajah et al. [12] have examined retrieval performance of individual and hybrid shape descriptor with the aim to find the most suitable shape decriptor for content based image retrieval.

In our paper, meticulous review of all recent shape extraction techniques for content based image retrieval is presented. The major contributions of this survey are listed as below,

- Different feature extraction techniques for content based image retrieval and open issues on shape representation techniques are given.
- Each shape based image retrieval technique is summarized in table with parameters like: invariance to rotation, translation, and scaling, affine transformation, distance metric used and improved performance.
- Detailed reviews of techniques which are not yet surveyed are given and those which are surveyed are enlisted for reference.
- Challenges and open research problems related to shape based image retrieval are discussed.

III. SHAPE FEATURE CATEGORIZATION

Several techniques are proposed in literature [5, 6, 7, 10, 12] for shape based image retrieval based on following parameters - space domain and transform domain, information preserving and non-information preserving and according to processing approaches. In this paper the basis for the classification is contour based and region based technique as proposed by MPEG7 standards [13]. The classified technique is based on whether shape boundary or shape interior is considered for deriving shape descriptors.

3.1 Contour Based Shape descriptors

Contour based shape descriptors [5, 7] use boundary information of shape. These descriptors are popular as they are easy to acquire, compute and robust in representation. Following are different descriptors based on contour

1.1.1 Fourier Descriptor (FD)

Fourier Descriptor is one of the widely used frequency transform for representing shape descriptor. Shape descriptor using FDs can be derived from different signatures such as complex coordinates, curvature, cumulative angular function and centroid distance of which centroid distance has been proved to be better[5].

In preprocessing stage of Fourier descriptor [7, 10], boundary information or coordinators are extracted from image by using edge detection or boundary tracing. Discrete Fourier coefficients are calculated from shape signature using Fourier transform. FD scale normalization is done by calculating ratio of magnitude value of each boundary pixel to magnitude value of initial pixel. In this magnitude values are considered whereas phase values are ignored.

1.1.1.1 *Fourier Descriptor with Brightness*

Zhang [14] proposed the variation of basic Fourier descriptor by adding the brightness value of the boundary pixel to the shape signature. Due to presence of brightness value, overall performance is better compared to basic Fourier descriptor in case of medical imaging application.

1.1.1.2 *Ellipse Shape Fourier Descriptor*

This descriptor [15] fragments edge contour of an object into sequence of ellipses. This ellipse based feature relies on Fourier based description of contour object. Feature vector for every ellipse is represented by its semi-major axis, semi-minor axis and its angle of orientation. This feature improves retrieval efficiency by using particle swarm optimization which is adequate for ellipse matching and upholding all the characteristics of Fourier descriptor except it is sensitive to selection of initial point.

1.1.1.3 *Radial Distance with Triangular Centroid Area (RDTCA) Signature*

Radial Distance with Triangular Centroid Area [16] signature accumulates Euclidean distance of contour point and centroid along with triangular area generated between centroid and respective boundary points with Fourier based description.

The inclusion of radial distance makes significant improvement in large databases compared to small databases.

1.1.1.4 *Smallest Rectangle Distance (SRD) signature*

Smallest Rectangle Distance signature [17] constitutes spatial relation between boundary points and rectangle sides covering object contour. It computes distance vector for contour points by measuring both horizontal and vertical distances of boundary points from nearby rectangular side. Due to time-efficient feature extraction, SRD signature has less computational complexity.

1.1.1.5 *Four Sides Distance (FSD)*

Four Side Distance signature [18] typically tries to capture spatial property of selective boundary points by generating feature vector for these points by computing major distances-from all sides of smallest rectangle which covers object contour. FSD is highly recommended Fourier based signature as it require as computation time.

1.1.1.6 *Modified Fourier Descriptors*

The Modified Fourier Descriptors [19] collectively use geometric and non-geometric information of local space. Initial steps are same as that of classical Fourier descriptor for generating geometric information of local space. However for computing non-geometric information gray value of boundary pixel is used. Combination of geometric and non-geometric features forms the feature signature. To obtain feature descriptor Fourier transform is applied to feature signature. The modified Fourier descriptors [19] are more discriminative than other Fourier descriptors.

1.1.1.7 *Normalized complex coordinates signature (NCC)*

Normalized Complex Coordinate Signature [20] is an extension of Fourier Descriptor [5, 7] using complex coordinates signature which led to an improvement in scale normalization. In case of Fourier descriptor to achieve scale normalization, coefficients are divided by magnitude of first harmonic. Whereas in NCC instead of magnitude of first harmonic, it is divided by sum of magnitude of all harmonics. NCC outperforms in terms of effectiveness and efficiency in shape retrieval.

1.1.1.8 *Multiscale Fourier Descriptor using Wavelet Transform*

Iivari Kunttu et.al [21] combined multiscale property of wavelet transform with simplicity of Fourier transform. The wavelet coefficients of boundary pixel are obtained at different scale and position using complex Gaussian wavelet. The wavelet coefficients obtained are variant to rotation, as they depend upon the starting point of boundary pixel and descriptor size depends upon the boundary length hence direct matching of different size descriptors is not possible using wavelet coefficients. Finally the shape feature descriptor is generated by overcoming the above difficulties of wavelet coefficients by applying Fourier transform. The proposed multiscale Fourier descriptor improves the retrieval performance without any upturn in computational complexity.

1.1.1.9 *WARP Signature*

WARP (Accurate Retrieval based on Phase) [22] is an innovative Fourier based method for retrieving relevant images from large database based on shape features. In classical Fourier descriptor [5,7], phase information is ignored to achieve rotation and starting point invariance. But in case of WARP incorporating the phase information has shown considerable gain in retrieval accuracy and recall level. But on the other hand using phase information, phase shifting problem arises with commonly used Euclidian distance in similarity matching. So in WARP, Dynamic Time Warping distance (DTW) is employed for similarity matching.

1.1.2 Wavelet Based Shape Features

Muwei Jian et.al [23] proposed the shape based retrieval system using wavelet transform for trademark image retrieval. In this method both tasks: edge detection and shape feature extraction are carried out using wavelet transform. For Edge detection, Peak analysis for threshold selection method based on wavelet transform is performed. Produced edge image is used to derive features from Wavelet transforms sub bands (HL, LH, HH). The four directional information (0, $\pi/4$, $3\pi/4$ and π) derived from sub bands is used to construct the feature vector, used for indexing the images. The two fold use of wavelet transform increases the efficiency of retrieval without complication of segmentation.

1.1.3 Ekombo Invariant Affine Fourier Descriptor

Ekombo et. al [24] derived the variation of Fourier descriptor to make it invariant to affine transformations and distortions. In this method [24] curve normalization is carried out by using moments and Principal Component Analysis (PCA) before computing coefficients of FD. Curve normalization is used to get the canonical curves, remove the effect of any possible rotation and adds to the dual signature which calculates radius and angles.

1.1.4 Curvature Scale Space (CSS)

CSS Based descriptor [11,49] was selected as the standard by a MPEG-7 core experiment after testing it with other descriptors. CSS descriptor captures the local features, concavity and convexity of the shape contour. Contour points are extracted from the boundary and then they are scale normalized for generating fixed number of contour points. CSS descriptor generation consist of two steps: contour map computation and peaks extraction. In contour map computation, curvature zero crossing points are computed and then are successively blurred by convoluting with Gaussian kernel of width, where the scale is increased at each level of blurring until no curvature zero-crossing points are calculated. Next the peaks are extracted by a separate process and normalized. This normalized peak values form the CSS descriptor.

1.1.5 Contour Points Distribution Histogram (CPDH)

Xin SHU et.al [25] designed a new contour based method on distribution of contour points. In this method the object is enclosed into minimum circumscribed circle which is then parted into several bins using concentric circle and equal interval angle. Contour points are counted in each bin and presented as descriptor using triplet value. CPDH is invariant to scale and translation, whereas partial rotation invariance is obtained in matching process. The majesty of method is easiness in computation of descriptor and object matching using Earth Mover's Distance (EMD) metric.

1.1.6 Distance Autocorrelogram (DAC)

Distance Autocorrelogram (DAC) [26] is the evolution of distance histogram. Distance histogram shows contour characteristics whereas it fails to incorporate spatial distribution characteristics.

In DAC, the descriptor is expressed by using the correlation between centroidal distances and neighboring pixels. DAC consists of five steps: Edge detection, computing centriodal distance matrix, normalization and quantization of centriodal matrix, counting neighboring elements. DAC is easy to realize and outperforms distance histogram.

1.1.7 Included Angle Histogram

The problem associated with general contour based technique of using varying number of boundary points to represent the shape and translation of boundary points is addressed in proposed method [27]. First the boundary points are detected, then vector is computed from the centroid to the boundary point and last to represent the image, included angle between pair of vector is computed. Included angle histrogram captures local (point) and global (angle) information, but has limitations to detect shape which include smooth curve arc.

1.1.8 Homotopic Deformation(HDBS)

Li Zhou et.al [28] aim was to design noise invariant shape descriptor using global features of the shape. In Homotopic Deformation, object is wrapped in minimum circumcircle. Path length from each point on circumcircle to object is used as shape signature. Derived shape signature is straight away used for similarity matching and proved to represent complex concave objects accurately.

1.1.9 Shape Salience descriptor using (Angular Relative Position & curvature value)

Glauco Vitor Pedrosa et al. [29] proposed feature descriptor is represented by an image salience points having high curvature value. Each saliency point consists of two values: angular relative position and curvature value. An angular relative position is an angle between the centroid, an arbitrary point and the saliency point. Curvature value of current saliency point is calculated by using the left and right neighbor saliency point's approximation. Dynamic programming is used for searching the relevant images by employing optimal correspondence between the saliency points of database and query image. This method is used to retrieve shape from the same class having different number of saliency points.

1.1.10 Scalable Shape Context

Scalable Shape Context (SSC) signature [30] modifies original Shape Context shape feature to be scale invariant, it computes corner points among boundary points of a shape with help of Harris-Laplace corner detector and then log-polar histogram bins are constructed around each corner point with 12 bins to record relative angle and 5 predefined concentric circles to record relative radial distance for contour points located in each histogram bins.

1.1.11 Minimum Bounding Circle Touch Points Vertex Angle Sequence (MBC-TPVAS)

Cyrus [10] introduced three variation of minimum bounding circle- MBC (MBC-TPAS, MBC-VAS, and MBC-TPVAS) with the objective to lower the computational cost and storage.

Features of the object contour are used for forming the shape signature. In each method first the object is enclosed in the circle called minimum bounding circle.

Depending upon the type, different MBC features such as number of touch points (TP) and angle sequences (AS/VAS) are identified. In MBC-TPVAS, VAS and TP are combined. The Fourier coefficients are obtained by applying DFT on extracted MBC shape signature.

1.1.12 Triangle Area Representation (TAR)

Triangle Area Representation [31] allows to record fine details of object contour. It computes area of triangle formed by boundary/contour points to constitute concavity/convexity of contour curvature across different scales. This allows making TAR signature noise resilient and invariant.

1.1.13 Multi-scale Triangle-Area Representation (MTAR)

Multiscale TAR signature [32] is modified TAR signature. TAR signature utilizes triangular forms generated with selective contour points of shape to aggregate concavity / convexity of contour curvature. Multiscale TAR applies wavelet transform to generate smoothed scale-space of shape boundary. From individual scale level, a TAR signature is extracted to get curve intensity across shape boundary, along with maxima and minima of concave/convex curvature points which makes MTAR shape feature highly robust to noise and boundary distortions.

1.1.14 Angular Histograms (AH)

Angular Histograms [33] for shape representation firstly computes centroid from sample points on shape boundary. A major-axis is obtained as radial distance between centroid and farthest point on shape contour. Then for every selective contour point, angle between horizontal x-axis and radial line connecting that point and centroid is calculated. These angles are thus robust to translation and scale transformation. But to make this rotation invariant, a shape contour is rotated by angle in such a way that major-axis gets aligned to horizontal x-axis, angle is calculated. The angles of selective contour points on normalized contour shape are distributed in number of buckets which in result generates angular histogram of angles of contour points for robust shape representation.

1.1.15 Angular radial partitioning (ARP)

Angular Radial Partitioning [34] was proposed with the goal to design a new shape descriptor which yields efficient, easy and effective similarity matching and also focuses on invariant properties. In the design process of ARP descriptor, edge detection and image size normalized is carried out in preprocessing stage. Then the edge image is divided into radials and sectors. Numbers of edge pixels in each sector are counted and so this method is said to be based on geometrical distribution. Finally extracted feature descriptor is compact in size, which can be used for fast retrieval in large image database.

1.1.16 Segment Saliences (SS)

Segment saliences descriptor [35] is twofold improvement over contour saliences descriptor. Location of concave point problem in contour salience descriptor is solved in segment salience by replacing it with salience length of contour segment. Lengths of contour segment will effectively speedup the matching process.

3.2 Region Based Shape Descriptors

Region based shape descriptors exploit both boundary and interior information for an object shape. As it captures the interior of shape, it can be used for non-connected shapes. Following are different techniques proposed in literature for region based shape description,

3.2.1 Image Moments (IM)

Image Moments [11, 36] are most commonly used descriptors for shape based object recognition. They are primarily based on theory of algebraic invariants. They are not only invariant to scale, translation and rotation but also to affine transformations. The six invariant moments are calculated by decomposing affine transformation.

3.2.2 Generic Fourier Descriptors (GFD)

Accuracy of contour based method varies depending upon the technique used for extracting boundary information. Generic Fourier descriptor [37] was proposed to overcome the drawback of contour based method by considering interior as well as boundary information of shape for representing descriptor. In GFD, 2D Fourier transform is applied on polar shape. Experimental results show GFD outperforms 1-D FD and MPEG-7 shape descriptors [7].

3.2.3 *Invariant Zernike Moments Descriptor (IZMD)*

Complex Zernike Moments (ZMs) are derived by using set of complex polynomials which form a complete orthogonal set over the interior of the circle. In many shape descriptors using ZM, only ZM magnitude coefficients are used and phase coefficients are ignored. But phase coefficients have shown significance in reconstruction of image. Shan Li [38] introduced a new Invariant Zernike Moments descriptor (IZMD) by combining magnitude and phase coefficients. In IMZD, scale and translation invariance is achieved by normalization whereas rotation invariance is achieved by applying phase correction method to ZM phase coefficients. IZMD has shown its robustness against noise and many image transformations.

3.2.4 Exact Legendre Moments (ELM)

In CBIR, image features are extracted from image moments, viz. MI, ZM, and LM have given good shape representation. But due to lack of orthogonality and high computational complexity of these moments, Ch.Srinivasa Rao et al. [39] use Exact Legendre Moments (ELM) for shape based image retrieval system. Support Vector Machine (SVM) classifier is used to increase the efficiency of proposed ELM for image retrieval.

3.2.5 Shape Adaptive Discrete Cosine Transform

Efficacy of a transformation scheme is laid in its ability to wrap up input data into as few transform coefficients as possible. This will allow quantizer to remove coefficients with small amplitudes without causing visual distortion in the reconstruction of an image. Due to SA-DCT, most of the energy will be converged in lower level frequencies so this will reduce the total amount of data that is required to describe an image. Shape adaptive DCT [41] applies 1-D DCT on user-specified region of image vertically. After extraction of vertical DCT components, horizontal 1-D DCT is performed on it to get minute description of user-selected shape rather than working on whole image. The advantage of using SA-DCT is that it works on user-specified region of an image thus gives user-defined semantic representation of an image. SA-DCT increases retrieval efficiency drastically with increase in recall rate and minimizes complexity of retrieval system.

3.2.6 Polar Raster Sampling Signature (PRSS)

Generally region based shape descriptor transforms the image into two dimensional signature function whereas Polar Raster Sampling Signature [42] inspirit of being region based is represented by one dimensional signature. PRSS firstly encloses shape image in polar raster grid then calculates number of pixel across each concentric circle and diameter. PRSS consists of two components, radius and angle for number of pixels computed. Performance of PRSS is outstanding as compared to existing region based methods.

3.2.7 Spherical Harmonics Descriptor (SHD)

3D model are created by decimating 2D image using connectivity. SHDs [43] are constructed from 3D model using spherical harmonics. The advantages of the SHD are, connectivity which helps in discriminating shapes, spherical harmonics represents images in spectral domain hence details are captured at multi-resolution which helps in indexing. SHD demonstrated good accuracy compared to Generic Fourier descriptor but at the rate of high computational complexity.

3.3 Hybrid (Global and Local Shape Features) Descriptors

3.3.1 Fourier Descriptor+ Krawtchouk Moment Invariants

Yanyan Wu and Yiquan Wu [44] showed that combining more than one dissimilar features, local or global improves retrieval accuracy at the expense of computational complexity. Compactness and normalized Fourier descriptor [5,7] are extracted as local features. Fourier descriptor has been proved invariant under many image transformations, but retrieval efficiency is reduced, due to the drawback of accurate edge detection or segmentation techniques. To overcome the drawback of local features, global features are extracted by using Krawtchouk moment of an image. Krawtchouk moments are discrete orthogonal moments, hence they is no need for spatial normalization.

3.3.2 Curvature and Distance to centroid+ Zernike moments

The hybrid method proposed by Chia-Hung Wei et al. [45] constructs invariant shape features are derived from both local and global features of the image. Local features are meant to express the interior details of the image, derived by using standard derivation of curvature and distance to centroid. Inorder to minimize redundant information of an image in feature descriptor, Zernike moments having orthogonality property is used to represent global features. The resultant P-R graph shows the hybrid descriptor outperforms individual descriptors.

3.3.3 Grid based Wavelet Descriptor

Yanyan Wu et al. [46] proposed image retrieval method is combination of local and global shape features to overcome the drawbacks of both region and boundary based techniques. Before deriving the local and global features, preprocessing steps are carried out by using Minimum Error thresholding and border extraction. For extracting local features grid based methods and for global features Discrete wavelet transform is used. This method outperform in terms of relevant image retrieval.

3.3.4 *Composite Shape Descriptor*

Composite shape descriptor [47] is a combination of Labeled-grid based feature and Grid based contour shape signature. In Labeled-grid based feature, a shape is partitioned into grid of equal-sized N*N cells with central cell to get overlapped with centroid of shape and value of N to be odd. Then area percentage for each grid cell is calculated by measuring total shape pixels present in each cell area. Every grid cell is now labeled as interior region (if shape pixel covers maximum cell area) else as boundary region (if shape pixel covers part of cell area) otherwise as background region. A labeled shape matrix is generated by assigning value as 1 to cell area which is near to shape centroid or else assigned value as 2 which are at a distant location from shape centroid. A final grid-based shape feature is obtained by probability of appearance of interior and boundary regions in the form of box shaped tracks on grid-based matrix. The probability of occurrence of interior/boundary regions at specified distance is computed as ratio of count of interior/boundary regions to total sum of interior/boundary regions. Secondly, a grid-based contour shape signature is computed by obtaining radial distance of contour points of boundary regions from shape centroid.

3.3.5 Composite Generic Fourier Descriptor (GFD)

Atul Sajjanhar et al. [48] integrated contour GFD and region GFD for retrieval of 2D images. Due to combination of contour and region based features, advantages become two fold. First contour GFD extracts connectivity information which helps in distinguishing shapes. Second region GFD extracts spectral information in frequency domain which extracts detail information at different resolution. Processing complexity is compensated for applications which require high accuracy.

IV. Dataset

Different feature descriptors work with different level of effectiveness depending upon characteristics of specific image dataset. Different dataset used by researchers for shape based image retrieval are MPEG-7, COIL-20, Wang's, Trademark, Medical, Fish, KIMIA99 and Swedish leaf. MPEG-7 is the most preferred dataset due to shape being considered as primitive component along with texture and color.

V. Comparative Analysis

Shape features are evaluated based on parameters listed below,

- Feature dimensionality: This property is now a norm for efficient indexing and faster retrieval hence it must be as optimized as possible. It is needed to transform the feature data from high dimensional order to an order of fewer dimensions. Feature dimensionality is considered to be a critical component for optimization of feature data. In order to avoid curse of dimensionality usually a procedure of dimensionality reduction is followed.
- Execution time: Every automated system should be efficient enough to deliver results in reasonable amount of time.
- Accuracy: This is a major requisite for information retrieval systems, typically measured in terms of precision/recall. Accuracy depicts how close retrieved images are to queried image.
- Invariance: Shape features must not get affected by variations made in position, angle and size of an image. The extracted features must be invariant to translation, rotation and scaling. It must also be as invariant as possible with affine transformation and noise.

VI. Challenges and Future Research Directions

This section covers the challenges discovered though the study and throws light upon future directions.

- A hybrid method has shown high retrieval accuracy but at the expense of high computational complexity for which a novel approach should be devised for reducing feature dimensionality.

Table 2: Performance Evaluation of different Shape Based Image retrieval system

Major Shape Features	Shape Features (Variants)		Invariance Parameters					Performance Metrics		
			T	R	S	A	N	Feature Dimensionality	Retrieval Accuracy	Computational Complexity
Edge / Contour / Boundary based shape features (Local)	Fourier Descriptor	Classical Fourier Descriptor [5,7]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Fourier Descriptor With Brightness[14]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Ellipse Shape Fourier Descriptor [15]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Radial Distance with Triangular Centroid Area Signature[16]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Smallest Rectangle Distance Signature[17]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Four Sides Distance Signature [18]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Modified Fourier Descriptor [19]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Normalized Complex Coordinates [20]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	Multiscale Fourier Descriptor using Wavelet Transform [21]	✓	✓	✓	✓	✓	Low	High	Low
	Fourier Descriptor	WARP Signature [22]	✓	✓	✓	✓	✓	Low	High	Low
	Wavelet Based Shape Features [23]		✓	✓	✓	✓	✓	-	High	Average
	Ekombo Invariant Affine Fourier Descriptor [24]		✓	✓	✓	✓	✓	Low	High	Low
	Curvature Scale Space Descriptor[11,49]		✓	✓	✓	×	×	Low	Low	High
	Contour Points Distribution Histogram [25]		✓	✓	✓	-	-	-	Low	Low
	Distance Autocorrelogram Descriptor [26]		✓	✓	✓	-	-	-	Average	Average
	Included Angle Histogram [27]		✓	✓	✓	-	-	-	High	Low
	Homotopic Deformation Signature[28]		✓	✓	✓	-	✓	-	High	-
	Shape Salience Descriptor [29]		✓	✓	✓	-	✓	Low	High	Low
	Scalable Shape Context[30]		✓	✓	✓	-	-	Low	High	-
	Minimum Bounding Circle [10]		✓	✓	✓	-	✓	Low	High	Low
	Triangle Area Representation [31]		✓	✓	✓	✓	✓	-	High	Low
	Multi-Scale Triangle-Area Representation [32]		✓	✓	✓	-	✓	-	High	Low
	Angular Histograms [33]		✓	✓	✓	-	-	-	-	-
	Angular Radial Partitioning [34]		✓	✓	✓	-	✓	Low	High	Low
	Segment Saliences Descriptor[35]		✓	✓	✓	-	-	Low	High	-
Region based shape features (Global)	Image Moments [11,36]		✓	✓	✓	✓	-	Low	High	High
	Generic Fourier Descriptors [37]		✓	✓	✓	✓	✓	Low	High	Low
	Invariant Zernike Moment Descriptor [38]		✓	✓	✓	✓	✓	High	High	High
	Exact Legendre Moments [39]		✓	✓	✓	-	✓	-	High	High
	Shape Adaptive Discrete Cosine Transform[41]		✓	✓	✓	✓	✓	Low	High	Low
	Polar Raster Sampling Signature[42]		✓	✓	✓	✓	✓	-	High	Low
	Spherical Harmonics Descriptor [43]		✓	✓	✓	-	-	-	High	High
Hybrid shape features	Fourier Descriptor+ Krawtchouk Moments [44]		✓	✓	✓	✓	✓	High	High	High
	Curvature And Distance To Centroid+ Zernike Moments[45]		✓	✓	✓	✓	✓	High	High	High
	Grid Based Wavelet Descriptor [46]		✓	✓	✓	✓	✓	High	High	High
	Composite Shape Descriptor[47]		✓	✓	✓	✓	✓	High	High	High
	Composite Generic Fourier Descriptor[48]		✓	✓	✓	✓	✓	High	High	High

- An adaptive technique could be formulated for construction of shape descriptor to process images of diverse characteristics and categories.
- The relevance feedback technique can be incorporated with existing techniques to address the problem of images having relatively similar semantic characteristics but represented by different low level features [45].
- Significant improvement in time efficiency can be achieved for feature descriptors by incorporating parallel computing approach for time-efficient feature extraction and similarity matching.
- Large amount of data can affect retrieval performance. To outweigh the problem high dimensional indexing techniques need to be explored.
- Majority of shape based image retrieval systems use Euclidean distance for performing matching operations. However Euclidean distance does not capture human visual perception. Thus effective distance measures must be devised which can capture semantics of an image for similarity matching and in turn enhance retrieval efficiency.
- Orthogonal transforms such as wavelets can be used to represent image with minimum amount of redundancy resulting into less memory requirement thus giving compact representation of a shape object.

VII. CONCLUSION

In this paper recent advancements in the field of shape based image retrieval are explored. The existing shape based retrieval approaches have been critically analyzed with major focus on invariant features they employed and their effectiveness against different transformations along with retrieval accuracy and feature dimensionality. Selecting appropriate feature extraction for image retrieval system is totally dependent on the application image set. Adequate efforts have been taken by research community in designing effective retrieval system but still there is a scope to reduce the semantic gap between human visual perception and retrieval systems.

Overall efficiency of shape based image retrieval system is evaulated considering time and space component. Comparative analysis of different shape descriptors employed by different image retrieval systems is summarized in Table 2. Evaluation is based on critical analysis of experiemental results stated in considered research papers. The performance of different shape descriptors is evaluated in terms of their invariance ability, compactness and retrieval accuracy.

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