JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 18, No. 9-10, September - October 2016, p. 878 - 883

Radial vectored features for pattern enveloping and retrieval

V. GOEL[a], B. S. SOHI[b], H. SINGH[c]
[a]*Digital Electronics and Communication Division, Centre for Development of Advanced Computing (C-DAC), Mohali – 160 071 India*
[b]*Department of Electronics and Communication Engineering, Chandigarh University, Gharuan, Mohali, India*
[c]*Department of Electronics and Communication Engineering, CEC, Landran, Mohali India*

Radial vectored features are presented to draw an envelope of the pattern under test and its retrieval. Enveloping a given pattern is an important activity while tracking a moving object. The ordered radial profile is used to draw the envelope of the pattern, while the sorted radial profile is used to identify/recognize/categorize the pattern under test. The radial profile is computed around the centre of mass of the binary pattern. Maximum and minimum radii are accounted for figure aspect and broad symmetry about x- and y-axis. Mean, variance, standard deviation of radii, area, perimeter and Euler number give the degree of matching of the pattern to that from the existing data base, otherwise a new category is generated.

(Received February 17, 2016; accepted September 29, 2016)

Keywords: Centre of Mass (CoM), Pattern Recognition, Radial Profile, Standard Deviation, Euler Number, Discrete Cosine Transform (dct)

1. Introduction

Pattern extraction from the given data set or image is the prime step in generating the identifiers. Identifiers are used in content based search algorithms, pattern matching and pattern recognition etc. A pattern in an image is defined as an object or a color profile spread over the entire image or in some part of an image. A feature vector for the pattern may be derived based on certain features extracted from the given data set or image under study or test.

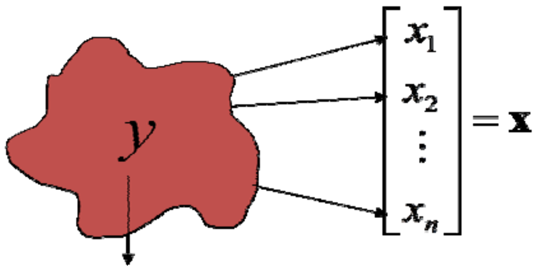

Fig. 1. A pattern Example and its Feature Vector X

Pattern analysis and recognition is one of the prime operations in image processing based system/application design. Automation in automobile parts identification system, identification of missing parts in a mechanical assembly and target recognition are few examples of pattern recognition based applications. Pattern recognition enables the computer to know what it is looking at via the image acquisition device like digital camera. If image acquisition devices are the eyes of the computer, then, pattern recognition algorithm is brain of the system that enables to identify the pattern under scanner.

Feature vector ($\mathbf{x} \in X$) is a vector of observations (measurements) and is a point in feature space. Based on weighted score of unknown pattern with trained set of parameters, the decision is deduced.

$$Q: X \rightarrow Y \tag{1}$$

Ideally a feature vector should bear the property of transform i.e. if V is the feature vector set of a pattern P and f1, f2, f3 … fn are the features, then,

$$V = P\{f_1, f_2, f_3 \ldots f_n\}, \text{ and } P = V^{-1}\{f_1, f_2, f_3 \ldots f_n\} \tag{2}$$

The above equation states that the pattern should be recovered fully from its feature vector set by taking inverse of the feature vector transform.

Many feature extraction algorithms exist that give a feature vector sufficiently rich in parameters to identify the respective pattern among different classes of the patterns. The uniqueness of the feature vector is appreciable and the accuracy of the pattern recognition/identification can be tested by increasing the test data base of pattern. However, to what degree the feature vector is unique, the inverse is not true i.e. a pattern cannot be recovered back from its respective feature vector. From study of literature survey, it is observed that the existing feature transforms like FFT, wavelet and dct are transformable from within their coefficients domain only.

Image is reconstructed by applying the inverse transform on respective coefficients. The transforms are rich in numbers in terms of their coefficients and vary as the input image size varies. This looses the degree of uniqueness of the feature vector and its reconstruction.

However, the degree of pattern recoverability can be enhanced if the feature vector is rich in nature i.e. features from multiple domain are included in the feature vector and then a reversible transform is computed that can absolutely reconstruct the image from its feature without loss of image information.

2. Related Works

Research in pattern analysis based on the feature vector set is continued since very beginning of the digital era and requires lot to be done. The prime objective is that the computer system should behave like a human when it comes across an image. A lot more work has been observed in literatures using different technique. Some of them are studied and discussed here below:

V. Arulmoz et al. [1] discussed the use of matlab neural tool box for pattern analysis in detail. Different patterns may be generated using the simple GUI and trained using the NN training provision. The same may be tested using the test option.

Guobin Ou et al. [2] presented neural network approach for multi class pattern. The neural network training features are extracted from the pattern after few image pre-processing operations applied on the pattern. The features are extracted from the binary image resulted out of threshold operation.

A. Mirzaaghazadeh et al. [3] proposed a gradient based neural network training using the pattern feature vector set. More are the features of a pattern, higher is the resolution at the output or more classes can be resolved.

Anil K. Jain et al. [4] presented a review of pattern analysis using statistical analysis. The patterns were analyzed in different domains like spatial, frequency and wavelet domain for pattern recognition accuracy determination.

A. Hassan et al. [5] discussed statistical processing chart for pattern analysis. Patterns were represented by their normalized features. A feature vector set is generated using different radii around centre of mass.

Sung-Bae Cho [6] presented that the hand written characters are also a class of patterns and can be identified using feature vector set. The feature vector set is unique for each of the hand written or typed fonts.

Yas Abbas Alsultanny et al. [7] proposed a hybrid approach between genetic algorithm and neural network was suggested here to classify the patterns into different class. The system consists of pattern segmentation, feature extraction and a classifier.

Raul C. Mureşan [8] suggested a pulse coded neural network (PCNN) for pattern classifier using different features when normalized with respect to pattern mean radius.

B.S. Manjunathi et al. [9] used Gabor wavelet features for input image texture classification and analysis that provided a comprehensive experimental evaluation. Based on textural properties, the patterns were classified into different classes using the minimum Euclidean distance.

Nikolaos V. Et al. [10] presented a gait representation and recognition system with new feature extraction. Random transform was taken as the basis for feature set generation. A considerable improvement was suggested by the researcher when the new feature set was used for gait analysis for identification of human activity.

Yu-Yao Wang et al. [11] proposed a novel method was proposed for face recognition. Its basic idea was to use a coarse to fine strategy based on Scale Invariant Feature Transform (SIFT) feature. To recognize a test sample, our method contains the three main steps: The first step identifies a certain number of candidates from training samples, depending on the Euclidean distance between the test sample and all training samples. The second step counts the numbers of well matched pairs of SIFT features between each candidate chosen in the first step and the test sample, then chooses several samples from candidates with the greater number of well matched pairs.

Joachim Hornegger et al. [12] presented appearance-based approach for object recognition and pose estimation. Non-linear image-to-image transform that is composed of linear mappings in order to reduce the feature vector size, the transforms are optimized by using selected special objective functions.

Dipankar Mudoi et al. [13] suggested Histogram of oriented gradients (HOG) in classification of vehicles on road. Vehicle tracking system is designed around the features analysis based on HOG. The classifier is designed based on Support Vector Machine (SVM).

Gandhani Savita et al. [14] suggested a framework composed of HSV color histogram as a color feature, BDIP and BVLC texture feature for the image retrieval. The precision and recall value obtained from the proposed system show significant improvements in image retrieval accuracy.

3. Invariance Control in Feature Vector

During pattern analysis in image processing, it is required that the feature vector is normalized with respect to pattern size, orientation and location. This enables the feature vector to be same for the pattern under test lying at any orientation, size and location. A feature vector is absolute if invariance control is not provisioned in the feature extraction algorithm. It is always the normalized feature vector that goes into the search engine on line or for further use. Normalized features set enables the system to identify the pattern appeared at any size, orientation or location.

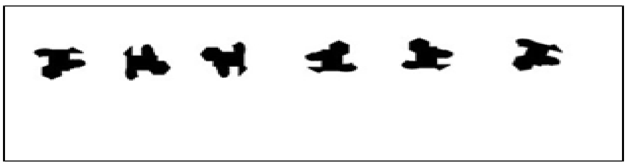

Fig. 2. Same Pattern at Different Orientations

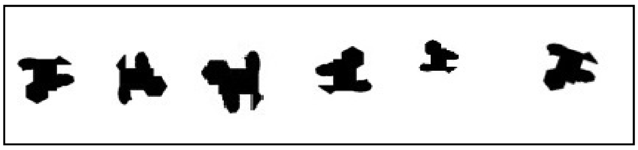

Fig. 3. Same Pattern in Different Sizes

Pattern recognition falls under the category of classification or description of objects by a computer system arising in steady, noisy or complex environments. Pattern recognition is attributed by feature extraction, normalization and making/generating of categories based on features either in supervised or unsupervised learning mode.

4. Radial Vectored Features Set

The spatial domain features may include radii profile, area, perimeter, figure aspect, Euler number and contour profile. The statistical domain features include standard deviation, variance and histogram based features. Input image is exposed to different image processing operations including enhancement, edge detection and binarization etc. Finally the binary image i.e. mono-chrome image with white back ground and black object/pattern or vice versa, is subjected to segmentation algorithms in order to get the different segments/patterns from the image. Following is the brief flow chart:

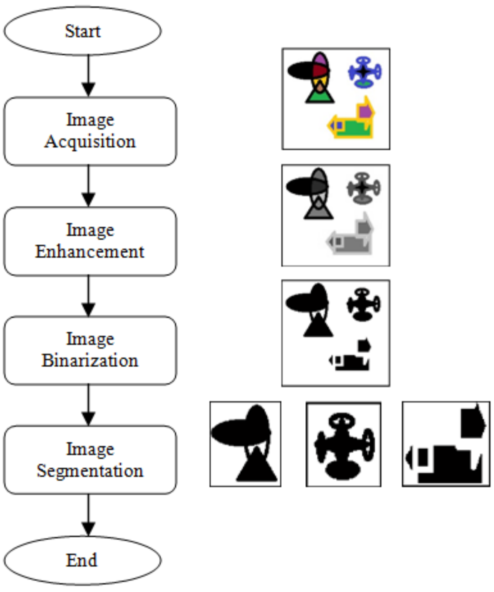

Fig. 4. Flow Chart

The segmented objects/patterns are normalized with respect to size and orientation. This enables the features to be same even at different zoom-in or out factor along with orientation. The size invariency is achieved by normalizing the features with respect to mean radius of the object taken around the centre of mass of the object under scan. The orientation is controlled by using the following orthogonal transformation:

$$\begin{bmatrix} X' \\ Y' \end{bmatrix} = \begin{bmatrix} \cos\alpha & -\sin\alpha \\ -\sin\alpha & \cos\alpha \end{bmatrix} . \begin{bmatrix} X \\ Y \end{bmatrix} \quad (3)$$

Where the coordinates (X, Y) are transformed to new coordinates (X', Y') at angle α.
The centre of mass (CoM) is computed by using the 1st order moments and is given by:

$$\mathrm{CoM}_x = \frac{\sum X}{N}, \quad \text{and} \quad \mathrm{CoM}_y = \frac{\sum Y}{N} \quad (4)$$

Where 'N' is the total no. pixels on the object.

The angle α is computed by using the 2nd order moments and is given by:

$$\alpha = \tan^{-1}\frac{X^2+Y^2}{X.Y} \quad (5)$$

Where (X, Y) are the object's pixel coordinates.

5. Radial Features Extraction

The pattern under test is divided into four quadrants taking its CoM as origin. All radii (equals in number to pixels on periphery i.e. Perimeter) are computed from CoM and stored in an array in the same order as they are extracted. Minimum and maximum radii are sorted out with respect to each quadrant and saved as MaxR1, MaxR2, MaxR3, MaxR4, MinR1, MinR2, MinR3 and MinR4 respectively.

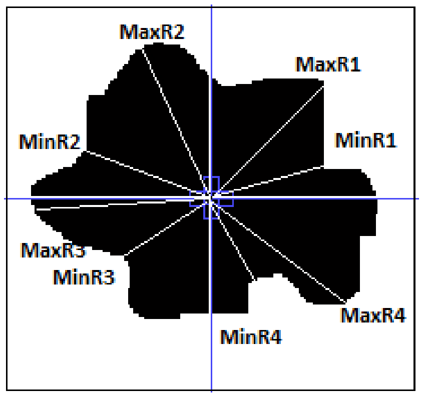

Fig. 5. Max. and Min. Radial Profile about CoM

The radial features are divided into following categories (Figure-5):

- -All radial coordinates from CoM to contour of the pattern
- -Sorted radii in descending order from CoM to contour of the pattern along with respective radial coordinates
- -Minimum radii in each quadrant
- -Maximum radii in each quadrant
- -Mean Radius
- -Variance of Radii

-Standard Deviation of Radii
-Perimeter
-Area

Computation of radii from CoM in real order means that the radii are arranged and stored in the respective quadrants. This is understood that if all the radii are plotted from CoM, the complete envelop of the pattern may be recovered. However, if maximum and minimum radii are used to make an envelope, a broad envelop is obtained. This is explained in below figures:

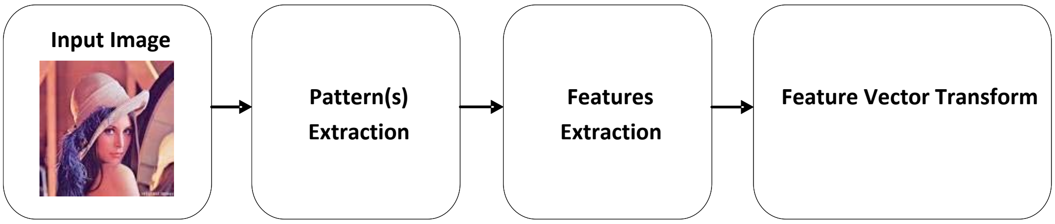

Fig. 6. Feature Vector Transform from Input Image

The feature vector transformability is determined by taking the inverse of the transform and evaluates the pattern shape and validates the same by original pattern. The prime objective is to retrieve the same pattern as that of the original pattern. The degree of shape matching is to be done initially manually. Later on an algorithm may be designed to test the algorithm for different shapes.

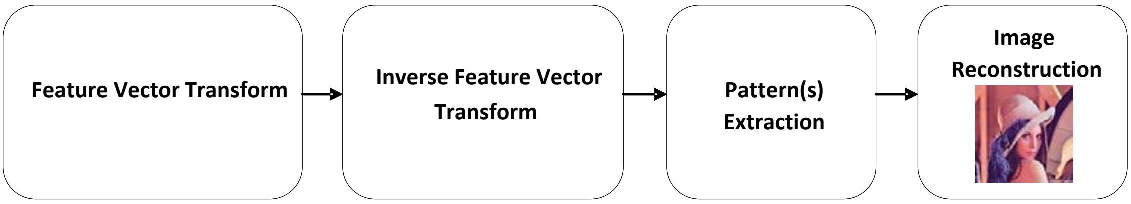

Fig. 7. Image Reconstruction from Inverse Feature Vector Transform

6. Pattern reconstruction from feature vector

The patterns are reconstructed using the respective feature vectors. Firstly, the maximum and minimum radii points are plotted in each quadrant. The maximum and minimum radii are the least radial points to be plotted. Further, the sorted radii are plotted in their respective quadrants and finally, all the radial points are joined to form the pattern envelop. The algorithm efficiency depends upon the minimum no. of radial points to be stored for a given pattern in order to get the maximum compression. It is critical task to judge the similarity of the reconstructed pattern to that of the original pattern. This is pattern enveloping.

The presented algorithm is implemented in following steps:

Step-1: Pattern Acquisition and Binarization
Step-2: Centre of Mass and Contour Extraction
Step-3: Divide the pattern into four quadrants about the centre of mass
Step-4: Compute all radii from centre of mass to contour of the pattern
Step-5: Sort minimum and maximum radii in each quadrants
Step-5: Sort the intercepts on each axis
Step-6: Store the radii profile with respect to their respective quadrant

7. Results and Discussions

Below Fig. 8 is the original pattern for test purposes along with some feature attributes computed using matlab. Figure 9 shows the centre of mass of the pattern, about which all the parameters are computed.

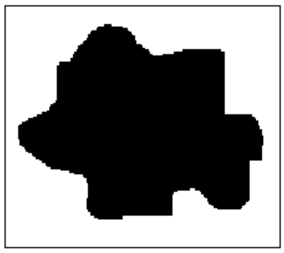

Fig. 8. Original Test Pattern

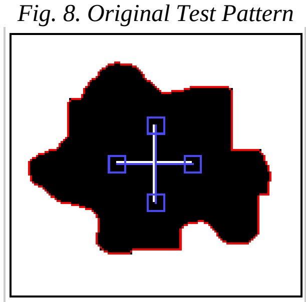

Fig. 9. Centre of Mass

Original Test Pattern Features

	Absolute Values	Normalized Values
Mean R	50.60	50.60
Perimeter	378.00	7.47
Area	8144.00	3.18
Std. Dev.	7.46	0.1475
Euler No.	1.00	1.00
Max. R1	58.01	1.15
Max. R2	65.01	1.28
Max. R3	65.19	1.29
Max. R4	64.07	1.27
Mean of Max.	63.07	1.25
Min. R1	37.22	0.74
Min. R2	41.01	0.81
Min. R3	39.70	0.78
Min. R4	35.34	0.70
Mean of Min.	38.32	0.76

Fig. 10. Test Pattern Attributes

Further, the radii computed around the centre of mass are listed in following table 1 in addition to the test pattern attributes as mentioned in figure 10. The pattern is reconstructed by using minimum and maximum radii, intercepts on each axis along with ‘N’ number of sorted minimum and maximum radii in each quadrant.

Table 1. Standard Deviation and Mean Radius for Reconstructed Patterns

Parameter	N=25 (Figure 10)	N=50 (Figure 11)	N=75 (Figure 12)	N=100 (Figure 13)
Std. Dev.	0.21	0.17	0.17	0.16
Mean R.	52.98	54.85	55.29	55.91

Following figures shows the pattern recovery or enveloping with different no. of radial points.

Fig. 11 N=25

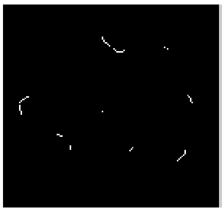

Fig. 12 N=50

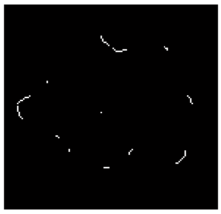

Fig. 13 N=75

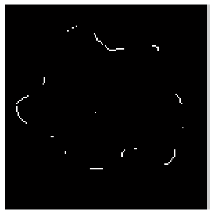

Fig. 14 N=100

Fig. 11 to 14. → Reconstructed Patterns using different No. of Radii (N)

8. Conclusion

The reconstructed patterns using different no. of radii along with minimum and maximum radii in each quadrant and intercepts on each axis can be observed in the figures 11 to 14. It is apparently cleared from the figures that as the no. of radii increases, the reconstructed pattern approaches towards the original test pattern. The standard deviation and mean radius parameters follow the same course as well. The reconstructed pattern can be completed by joining the points in order to compute the remaining parameters like perimeter, area and Euler number. The algorithm is developed using matlab version 7.5. Reconstructed pattern can be approximated exactly to its original shape in ideal case i.e. if all the radii are used for reconstruction. However, use of minimum number of radii is the prime objective for efficient digital memory use. The number of radii needs to be optimized to a minimum for the reconstructed pattern to be closest to its original one. This enhances the algorithm’s efficacy in terms of strong correlation of pattern features to its shape.

References

[1] V. Arulmoz, International Journal of Wisdom Based Computing **1**(2), 59 (2011).

[2] Guobin Ou, Yi Lu Murphey, Society, Elsevier, Pattern Recognition **40**, 4 (2007)

[3] A. Mirzaaghazadeh, H. Motameni, M. Karshenas, H. Nematzadeh, World Academy of Science, Engineering and Technology **33**, 88 (2007).

[4] Anil K. Jain, Robert P.W. Duin, Jianchang Mao, IEEE Transactions on Pattern Analysis and Machine Intelligence **22**, No. 1 (2000).

[5] A. Hassan, M. Shariff Nabi Bakshi, A. M. Shahroun, H. Jamaluddin Int. J. Prod. Res. **41**(7), 1587 (2003).

[6] Sung-Bae Cho, IEEE Transactions on Neural Networks **8**, 1 (1997).

[7] Yas Abbas Alsultanny,Musbah M. Aqel Neurocomputing, Elsevier **51,** 237 (2003).

[8] Raul C. Mureşan, Personal Research Center, P-ta Cipariu, Nr. 9, Ap. 17.

[9] B.S. Manjunathi, W. Y. Ma, IEEE transactions on pattern analysis and machine intelligence, **18(**8), 837 (1996).

[10] Nikolaos V. Boulgouris, Zhiwei X. Chi, IEEE Transactions on Image Processing **16**, No. 3 (2007).

[11] Yu-Yao Wang, Zheng-Ming Li, Long Wang, Min Wang, Journal of Information Hiding and Multimedia Signal Processing, Ubiquitous International **4**, No. 2 (2013).

[12] Joachim Hornegger, Heinrich Niemann, Robert Risack, Pattern Recognition by Pattern Recognition Society, pp. 209, (2000)
[13] Dipankar Mudoi, Parismita A. Kashyap, International Conference on Signal Processing and Integrated Networks (SPIN), pp 202 (2014),
[14] Yu-Yao Wang, Zheng-Ming Li, Long Wang, Min Wang, Journal of Information Hiding and Multimedia Signal Processing, Ubiquitous International **4**(2), 73 (2013).
[15] Gandhani Savita, Bhujade Rakesh, Singhal Amit, Third International Conference on Computational Intelligence and Information Technology CIIT, pp 353 (2013)

*Corresponding author: vikaskgol@gmail.com