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Geometric Pattern Recognition System based on Statistical Parameters using Image Processing

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Abstract—
The presented paper deals with the automatic visual inspection of the geometric patterns to recognise and classify. The scheme used for the classification of geometric patterns consists of four steps: 1) Pattern Generation 2) Making the pattern Rotation Invariant 3) Feature extraction and 3) Recognition and Classification. The pattern is generated by using any imaging tool e.g. by using paint-brush. The pattern is then made rotation independent by applying orthogonal transformation. After this, statistical features like, maximum radii in each quadrant, intercepts on each axis, perimeter, standard deviation, figure aspect and area, are computed from the image. The set of data of statistical parameters of each pattern so obtained is normalised to mean radius and stored for classification/ categorization purposes.

Keywords—*Pattern recognition, image processing, statistical parameters*

I. INTRODUCTION

Geometric pattern recognition is an exercise carried out to extract statistical parameters, verify the properties and specifications that the pattern must meet. The paper emphasis on an automatic machine vision system to recognize standard geometric patterns e.g. semi-circle, circle, line, square, rectangle of different aspect ratio, ellipse of different aspect ratio and regular pentagon and hexagon. In this paper, some statistical features have been extracted for standard geometrical shapes [1]. For instance, a perfect circle should have zero standard deviation of radii taken from the centre of gravity, unit mean radius, perimeter, multiple of 2π, unit figure aspect, and unit intercepts on axis and unit radii in each quadrant. Similarly all the geometrical shapes may be attributed with certain set of statistical parameters, on the basis of which, any pattern may be recognized and categorized.

II. STATISTICAL FEATURES FOR CLASSIFICATION OF GEOMETRIC PATTERNS

Following statistical features are computed from the analysis of the pattern with respect to centre of gravity for categorization:

[a] Normalised Maximum Radii in each Quadrant represented by R_1, R_2, R_3, and R_4. See fig. (1)

[b] Intercepts on each axis represented by X_1, X_2, Y_1 and Y_2 with respect to centre of gravity of object. See fig. (1).

[c] Mean Radius (R_M)

[d] Figure Aspect i.e. length to width ratio (FA)
$FA= (X_1 + X_2) / (Y_1 + Y_2)$

[e] Normalised Perimeter (Np)
N_p = Total no. of pixels at the contour of object / R_M

[f] Normalised Standard deviation of radii taken from centre of gravity of object (NSD).
$SD= \sqrt{[(Ri – R_M)2 /N_p]}$
$NSD = SD/ R_M$

Where R_M, and R_i are the mean radius and i_{th} radius i.e. distance of i_{th} pixel on contour of the pattern from its centre of gravity.

[g] Normalised area (NA) of the pattern.
Normalised area = Total pixels on objects / R_M^2

All features are normalized with respect to mean radius of the pattern. It makes all the statistical features independent of size of the pattern. The set of described statistical features may be termed as figures of merit to classify an object.

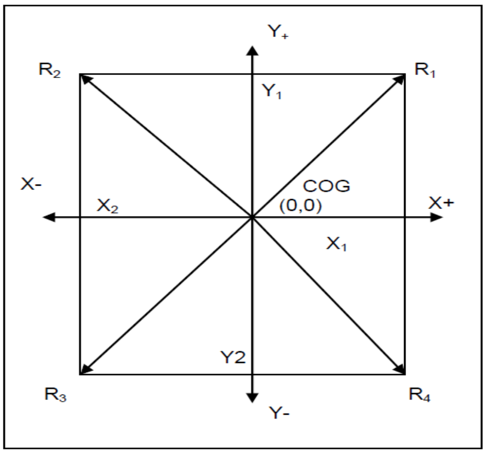

Fig. 1 Pattern Statistical Parameters

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In Fig. 1, R_1 R_2 R_3 and R_4 represent normalized maximum radii in each quadrant and X_1 X_2 Y_1 and Y_2 represent intercepts on each axis.

III. PATTERN GENERATION

Geometric patterns are generated using Paint-Brush tool with white background and colour pattern. The image is stored in 256 grey levels BMP format of size 256 x 256 pixels unit. This results in binary image with white background and black colours pattern of interest.

IV. ALGORITHM : FEATURE EXTRACTION

1) Centre of Gravity: All features are extracted with respect to centre of gravity (COG) of the object of interest. The COG is obtained by weight – averaging method [3].

$$Gx = (1/N) \sum Xi$$

And $$Gy = (1/N) \sum Yi$$

Where (Gx,Gy) is the co-ordinate of COG and (Xi,Yi) and 'N' are the co-ordinates of ith pixel and total no. of pixel on the object respectively.

2) Contour Extraction: *Contour of the object is extract by using the Robert's operator [8]:*

Following 3x3 kernel is used for contour extraction:

P_8	P_1	P_2
P_7	P_0	P_3
P_6	P_5	P_4

Where P_i is pixel color level.

Background Color = W (White)
Pattern Color = B (Black)
Contour Color = C (blue)
Algorithm:

If P1 - P0 != 0
Or P2 - P0 != 0
Or P3 - P0 != 0
Or P4 - P0 != 0
Or P5 - P0 != 0
Or P6 - P0 != 0
Or P7 - P0 != 0
Or P8 - P0 != 0

Then P_0 = C
i.e. P_0 is the contour pixel.

3) Rotation Invariant: After COG and contour extraction, a X-Y co-ordinate system is established taking COG as origin (0,0). This makes the established co-ordinate system for each image pattern, position invariant. Also, the co-ordinate system is made rotation invariant [6] so that if the object is rotated by an angle say α (angle of rotation of object axis), the features are not changed for the same object. This is achieved by using the following orthogonal transformation of rotation:

$$\begin{pmatrix} X' \\ Y' \end{pmatrix} = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \times \begin{pmatrix} X \\ Y \end{pmatrix}$$

Where (X',Y') is the new co-ordinate when axis is rotated at an angle α , with respect to old (X,Y) Co- ordinate axis[5].

As now the co-ordinate system is position invariant and rotation invariant, the statistical features, as described in section II can be computed from the pattern. The data for various standard geometrical shapes and some irregular shapes has been computed and compiled in a table given in next section.

4) Radii Computation: Radii are computed using the following coordinate formula:

$$R = \sqrt{\{ (G_x - X_1)^2 + (G_y - Y_1)^2 \}}$$

Where (G_x,G_y) and (X_1,Y_1) are coordinates of COG and pixel on contour of the pattern.

Similarly, intercepts on each axis are computed by following the pixels on contour and COG.

Mean Radius is determined by:

Mean Radii $R_M = (1 / N) \sum R_i$, where N is the total no. pixels on contour.

Maximum and Min. radii in each quadrant are computed by comparison method computationally.

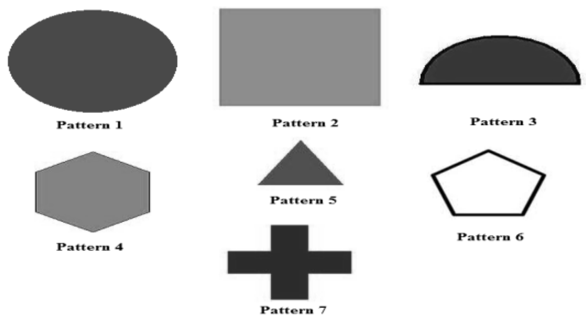

Fig. 2 Objects: Standard Geometrical Patterns

5) Recognition

The recognition process is based on rules made on the basis of analysis of data for different patterns. The data for some standard geometrical patterns and some irregular actual patterns found on material's surface are given in table 1 respectively.

A software program for computing the above has been developed that can compute all the above mentioned statistical parameters for a given pattern and tubulise them. If a pattern other than the stored one is observed, it is added to the list. This way a wide set of parameters can be generated and analysed using the program and a good classifiers for different patterns can be developed.

Table 1 Standard Geometrical Patterns Parameters obtained after computation Using Image Processing

S.No.	Parameters	Circle	Square	Semi-Circle	Reg. Hexagon	Eq. Triangle	Reg. Pentagon	Cross
1	Perimeter	6.28	7	6.49	6	7	6.13	9.85
2	Area	3.14	1	0.12	3.14	2.8	3.20	3.26
3	Mean Radius	1.00	1.0	1.00	1.0	1.0	1.00	1.00
4	Standard Deviation	0.00	0.25	0.43	0.15	0.35	0.20	0.30
5	Figure Aspect	1.00	1	0.56	1	1.50	1.00	1.00
6	Max R1	1.00	1.25	1.20	1.15	1.5	1.20	1.30
7	Max R2	1.00	1.25	1.20	1.15	1.5	1.20	1.30
8	Max R3	1.00	1.25	1.47	1.15	1.4	1.12	1.30
9	Max R4	1.00	1.25	1.46	1.15	1.4	1.12	1.30
10	Mean of Max R	1.00	1.25	1.33	1.15	1.45	1.15	1.30
11	Min R1	1.00	0.85	0.74	0.90	0.7	0.90	0.53
12	Min R2	1.00	0.85	0.74	0.90	0.7	0.89	0.53
13	Min R3	1.00	0.85	0.59	0.90	0.8	0.86	0.53
14	Min R4	1.00	0.85	0.59	0.90	0.8	0.86	0.53
15	Mean of Min R	1.00	0.85	0.67	0.90	0.75	0.88	0.53
16	Intercept on +ve X-Axis	1.00	0.90	1.20	1.0	0.8	1.02	1.25
17	Intercept on -ve X-Axis	1.00	0.90	1.20	1.0	0.8	1.02	1.25
18	Intercept on +ve Y-Axis	1.00	0.90	0.76	1.0	1.5	1.06	1.25
19	Intercept on -ve Y-Axis	1.00	0.90	0.59	1.0	0.8	0.86	1.25

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5) Results and Conclusion

On analysis of data given in table 1 with respect to patterns from 1 to 7 in fig.2, it is found that each class has a unique set of features. The normalized standard deviation of radii from the centre of gravity is the most important parameter in deciding the symmetry of the object about its centre of gravity. If normalized standard deviation is zero, it shows that the object is a perfect circle.

The other parameters like R_1 R_2 R_3 and R_4 and X_1 X_2 Y_1 and Y_2 (all equals in case of circle) supports the symmetry of the object and its shape recognition. The normalised perimeter (2π, in case of circle) and area (π, in case of circle) are the two other parameters, which confirm the shape of the object. Thus the statistical parameters for different geometrical patterns enable a computer to classify the defects.

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