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Human face detection using eigenvalues and DCT

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Abstract: **In this paper, the elliptical shape of the silhouette of the human head is used to detect his/her presence in a photograph. This method uses the ratio of the Eigenvalues of the covariance matrix of the outer edge image of the head. If the ratio falls within the limits (as will be seen later), then it can be concluded that the image consists of a human face.**

Keywords: **Human Face Detection, Discrete Cosine Transform (DCT), Eigenvalues, Covariance Matrix.**

I. INTRODUCTION

Ellipse detection [3] is one of the key problems in image processing [5].Various approaches have been suggested for detecting the ellipse and estimating the associated parameters. In most of the existing methods various authors have used the major and minor axis lengths of the ellipse to find the various parameters associated with it [1]. Many authors have used the idea based on the detection of the symmetric axes from contours in a Hough-based approach [2].
On the other hand, Prakash [1] [2] and Rajesh [1] [2] have proposed a method which uses the Eigenvalues of covariance matrix of the edge image to find the shape of the object present in the image [1]. Then they use Circular Hough Transform to find the approximate center of the ellipse, which represents the human face and then Raster Scan Algorithm is used to construct an ellipse to highlight the face [2]. The images they used are the edge images obtained from the gray scale image [5].
Here the same methodology is applied to an image which consists of the outer boundary of the head [5].

II. METHODOLOGY

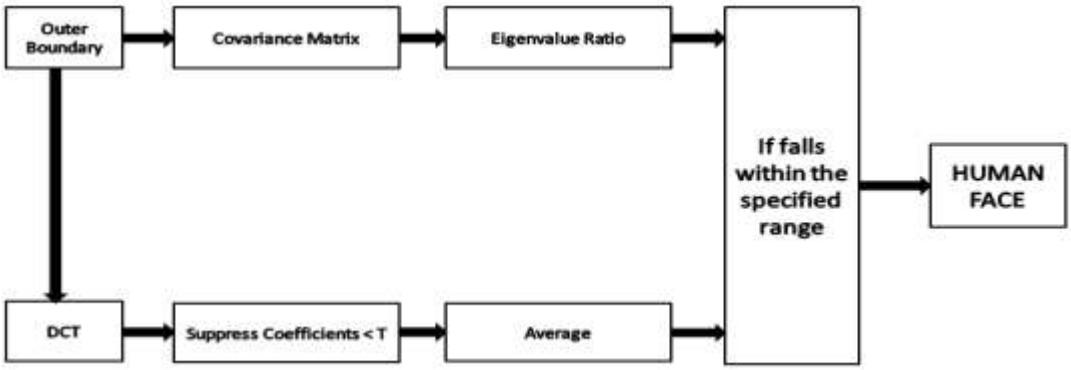
DCT coefficients and eigenvalues are used for detecting the face in an image. DCT is mainly used for image compression purposes and is known for its energy compaction. This means that much of the energy contained in the image can be represented by a significant few DCT coefficients. Hence applying a suitable threshold, only these significant coefficients are used for the analysis.

The eigenvalues of the covariance matrix outer boundary segment can be used to determine the shape the object in the image represents. The eigenvalues represent the perpendicular dimensions of the shape. If one eigenvalue is greater than the other, the object represents an ellipse. If both eigenvalues are equal, the object represents circle. If one of the eigenvalues is zero, there is a straight line in this picture.

Hence using the above two parameters together can be helpful in detecting the presence of a human.

A. STEPS

1. Obtain the outer edge of the object present in the image [5].
2. Find the co-ordinates of the points in the image where the edge is present in the image.
3. Find the covariance matrix of this edge segment [4].
4. Find the large and small Eigenvalues of this covariance matrix [1] .
5. Find the ratio of the large to the small Eigen value (λ_l/λ_s).
6. Take the DCT of the edged image [5] [6].
7. Suppress all the coefficients which are less than zero and retain others.
8. Find the average of the remaining coefficients.
9. If the ratio of the Eigenvalues fall within the range (1.1, 1.9), and the value of the calculated average falls within (0.02,0.06) then it can be concluded that the image consists of a human face (assumed to be elliptical).



B. CONCEPT

Let X, Y be the vectors which contain the x, y co-ordinates of the outer edge of the object in the image.
The covariance matrix [1], C is found by:

$$C = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix}$$

$$c_{11} = \frac{1}{n}\sum x_j^2 - c_x^2$$

$$c_{12}=c_{21}=\frac{1}{n}\sum x_j y_j - c_x c_y$$

$$c_{22}=\frac{1}{n}\sum y_j^2 - c_y^2$$

where, $c_x = \frac{1}{n}\sum x_j$; $c_y = \frac{1}{n}\sum y_j$ and
n = total number of co-ordinates.
The Eigenvalues of the matrix c can be used to extract the shape information about a curve.
The Eigenvalues are:

$$\lambda_l = \frac{1}{2}\left[c_{11} + c_{22} + \sqrt{(c_{11} - c_{22})^2 + 4{c_{12}}^2}\right]$$

$$\lambda_s = \frac{1}{2}\left[c_{11} + c_{22} - \sqrt{(c_{11} - c_{22})^2 + 4{c_{12}}^2}\right]$$

- For a straight line, the value of λ_s is nearly zero.
- For a circular shape, λ_l is nearly equal to λ_s.
- For an ellipse, λ_l is greater than λ_s.

A set of images are taken and the ratio large to small Eigenvalue (λ_l/λ_s) is calculated. The values for human face were found to be in the range of 1.1 to 1.9.

To make the process more efficient, Discrete Cosine Transform (DCT) is used.

$$\mathbf{B_{pq}} = \alpha_p \alpha_q \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} A_{mn} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2n+1)q}{2N}$$

$$0 \le p \le M-1$$
$$0 \le q \le N-1$$

$$\alpha_p = \begin{cases} \frac{1}{\sqrt{M}}, & p = 0 \\ \sqrt{\frac{2}{M}}, & p \neq 0 \end{cases} \qquad \alpha_q = \begin{cases} \frac{1}{\sqrt{N}}, & q = 0 \\ \sqrt{\frac{2}{N}}, & q \neq 0 \end{cases}$$

DCT of the edged image is taken and found out its coefficients. All the coefficient values less than zero are suppressed and the other values are retained. The average of the remaining coefficients is taken.
Now instead of only checking the range of the Eigenvalues ratio, the range of the average value of DCT coefficients is also checked. If the value of ratio falls in the range 1.1-1.9 and average of coefficients falls in the range of 0.02-0.06 then it can be concluded that the image contains a human face.

III. EXPERIMENTAL RESULTS

This section presents the results of the application of the proposed methodology to a random set of images downloaded from the internet. The results are as follows:

Here, R = Eigen Value Ratio λ_l/λ_s and A = Average of DCT coefficients

R = 18.8719 R = 1.131 R = 1.1774 R= 1.6958
A = 0.0162 A = 0.0469 A = 0.0446 A = 0.0589

R = 1.3779 R =12.5033 R = 26.2132 R = 1.4011
A = 0.046 A= 0.0201 A = 0.0161 A = 0.0433

R = 1.8795 R = 2.3643 R = 1.1173 R = 1.3487
A = 0.0345 A = 0.0588 A = 0.0501 A = 0.0479

R = 1.0958 R = 1.3965 R = 2.694 R = 1.445
A = 0.0413 A = 0.0369 A = 0.0423 A = 0.0542



R = 28.219 R = 56.996 R = 1.22
A = 0.0208 A = 0.0168 A = 0.0608

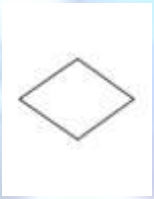


R = 1.8252 R = 26.063 R = 1.3272
A = 0.0605 A = 0.019 A = 0.0593



R = 1.390 R = 2.1953 R = 1.1547
A = 0.0678 A = 0.0426 A = 0.0592





R = 13.694 R = 219.6414 R = 4.5811
A = 0.0363 A = 0.0028 A = 0.0607

R = 10.6340
A = 0.0271

IV. CONCLUSION

The method suggested here is efficient, fast and simple. It is based on the assumption that there is a single person in the scene with light background. The use of DCT helps improving the efficiency of the method by distinguishing light and bright background. Of the 29 images considered, the method worked for 21 images, i.e. giving an efficiency of nearly 70%. The reason why this method didn't work for the other 9 images is because of the relatively darker background in those images. The algorithms based on Hough Transform used in other papers require more memory and high computational time. Also, avoiding the use of Raster Scan Algorithm saves a lot of complexity.

If the Eigenvalue ratio falls in the range 1.1-1.9 and average of coefficients falls in the range of 0.02-0.06, then it can be concluded that the image contains a human face (with a light background).

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