Eye Corner Detection

A thesis submitted in partial requirements for the degree of

Bachelor of Technology in Computer Science and Engineering

By

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Certificate

This is to certify that this report, bearing title Eye Corner Detection, presented by S.Vineela in partial fulfilment for the requirements for the award of Bachelor of Technology Degree in the field of Computer Science and Engineering at National Institute of Technology, Rourkela (Deemed University) .This is the project done by her under my supervision and guidance. To the best of my knowledge, the content in this report has not been presented to any other University or Institute for the award of any Degree.

Place : NIT Rourkela
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I would like to thank my parents for their blessings for the successful completion of this project.

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Declaration

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Abstract

Detection of corners of the eye is a good research topic.It plays an important role in multiple tasks performed in the field of Computer Vision.It also plays a key role in biometric systems.In this thesis,initially,the existing corner detection methods are discussed.Using Hough transform line,circle and ellipse were found out in the given image.The proposed work includes,finding the eye region in the given face image using Template Matching method.Later on,we fit a rectangle to the matched eye region.And then,we find out the corners of the rectangle and approximate them to be the corners of the eye.

Keywords:Harris Corner Detector,Sobel Interest Point Detector,Shi-Tomasi Corner Detector,Roberts cross Edge Detector,Hough Transform,Template Matching.

Contents

Chapter 1

Introduction

The detection of corners is widely used in computer vision to detect particular features and get some inference from the input images.The areas where,corner detection is used is video tracking,image mosaicing,3D modelling,object recognition,motion detection,panorama stitching,etc,.Intersection of two edges is a corner.In an edge,the change of intensity is constant along the edge direction.But,in a corner,change in intensity is in both directions.An interest point in an image,can be defined as a well defined position,and which can be accurately detected.There are many kinds of interest point detectors,available.For example,Harris corner detector,Sobel corner detector,Prewitt corner detector,Moravec corner detector etc,.Each of the above mentioned corner detection algorithms will be discussed later,in this thesis.The aim of this thesis,is to propose work,to find the corners of an eye.It is a good research topic in the recent years.Eye corner detection is widely used in assissted-driving and biometric systems.There is a high need of a robust eye corner detector.Our main topic of interest is to detect both the nasal and temporal eye corners of facial images.Eye corners are treated as key points in the biometric systems.The eye corners should be detected accurately in all conditions like ,gazed look ,levels of eye closure,expression,lighting conditions, makeover,etc,.

Chapter 2
Literature Review

In this section,the existing interest point detection algorithms will be discussed.

2.1 Harris Corner Detector

We consider a window of small size,generally 3*3, 7*7,etc,.Shifting the window in any direction should yield a considerable amount of change in the intensities of pixels.Three cases arise while we are shifting the window across the image.They are flat region i.e,no change in the intensities of the pixels,under consideration,change in one direction i.e,an edge and change in intensities of pixels detected in both the directions.Each case,described above is determined by mathematical approach given by Harris Corner Detector.The change in intensity is calculated by the formula

$$S(x,y) = \sum_u \sum_v w(u,v)(I(u+x,v+y) - I(u,v))^2 \qquad (2.1.1)$$

where,w(u,v) is the window function, I(x,y) is the intensity value at pixel (x,y), I(x+u,y+v) is the intensity of the pixel (x+u,y+v).

$$S(x,y) \approx \begin{pmatrix} x & y \end{pmatrix} A \begin{pmatrix} x \\ y \end{pmatrix} \qquad (2.1.2)$$

$$A = \sum_u \sum_v w(u,v) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \qquad (2.1.3)$$

Matrix A is called the Harris matrix.Let the eigen values of matrix A be k1 and k2
1)If k1 and k1 are very low then,it is not a region of interest.
2)If k1 is very low and k2 has a very high value,then it is an edge
3) If k1 and k2 has a very high ,then it is a corner point.

2.2 Sobel Interest Point Detector

The Sobel operator uses a 3*3 matrix to find the horizontal as well as vertical edges in the given image.Here,let A be the original image.

$$G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} * A \qquad (2.2.1)$$

gives edges in vertical direction.

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * A \qquad (2.2.2)$$

gives edges in horizontal direction.The gradient approximation,at each point in the image is given by

$$G = \sqrt{G_x^2 + G_y^2} \qquad (2.2.3)$$

2.3 Prewitt Interest Point Detector

The Sobel operator uses a 3*3 matrix to find the horizontal as well as vertical edges in the given image.Here,let A be the original image.

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -1 & 0 & +1 \\ -1 & 0 & +1 \end{bmatrix} * A \qquad (2.3.1)$$

gives edges in horizontal direction.

$$G_x = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} * A \qquad (2.3.2)$$

gives edges in horizontal direction.

The gradient approximation,at each point in the image is given by

$$G = \sqrt{G_x^2 + G_y^2} \tag{2.3.3}$$

2.4 Shi-Tomasi Corner Detector

Shifting the window in any direction should yield a considerable amount of change in the intensities of pixels.Three cases arise while we are shifting the window across the image.
1)flat region i.e,no change in the intensities of the pixels
2)change in one direction i.e,an edge
3)change in intensities of pixels detected in both the directions
Mathematical approach followed in Shi-Tomasi Corner Detector is :

$$S(x,y) = \sum_u \sum_v w(u,v)(I(u+x, v+y) - I(u,v))^2 \tag{2.4.1}$$

The above formula calculates the change in intensity at pixel position I(x,y) and I(x+u,y+v)

$$S(x,y) \approx \begin{pmatrix} x & y \end{pmatrix} A \begin{pmatrix} x \\ y \end{pmatrix} \tag{2.4.2}$$

$$A = \sum_u \sum_v w(u,v) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \tag{2.4.3}$$

w(u,v) is the window function used in this corner detection algorithm.
Let the eigen values of matrix A be k1 and k2
The scoring function in Shi-Tomasi Corner Detector is given by:
R = min (k1 , k2)

2.5 Roberts cross Edge Detector

Robert cross operator is used in computer vision for edge detection.The basic idea,the Roberts cross operator follows is that ,it approximates the gradient of the image with the help of discrete differentiation,achieved by calculating the differentiating the sum of the squares of the differences between the adjacent pixels,which are diagonal,with respect to each other.

An edge detector,should have the following properties.

1)The edges,which are detected by the operator,should be well defined and accurate.

2)The background noise or disturbance should be as small as possible.

3)The intensity of the edges detected should correspond to what human percieves.

$$y_{i,j} = \sqrt{x_{i,j}} \qquad (2.5.1)$$

$$z_{i,j} = \sqrt{(y_{i,j} - y_{i+1,j+1})^2 + (y_{i+1,j} - y_{i,j+1})^2} \qquad (2.5.2)$$

where,

Initial intensity value is x

Computed derivative is denoted by z

i,j represent the x and y co ordinate of the pixel image.

The output of the above equation highlight the edges in diagonal direction.

Let,

$$A = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \qquad (2.5.3)$$

$$B = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \qquad (2.5.4)$$

We convolve the given image withe given kernels A and B.

$$G_x(x, y) \qquad (2.5.5)$$

and

$$G_y(x, y) \qquad (2.5.6)$$

are the results after convolution.The gradient can be defined as

$$\triangledown I(x, y) \approx G(x, y) \approx \sqrt{G_x^2 + G_y^2} \qquad (2.5.7)$$

The direction of the gradient can be defined as

$$\Theta(x, y) = \arctan \frac{G_y(x, y)}{G_x(x, y)} \qquad (2.5.8)$$

Chapter 3

Eye Corner Detection

The input in our case will be a face image.Now,lets see,how we extract the eye region from the given input face image.We transform the given input image from RGB space to YcbCr space.The transformation is done in the following way:

$$1)Y = (77/256)*R + (150/256)*G + (29/256)*B; \tag{3.1}$$

$$Cb = (44/256)*R \quad (87/256)*G + (131/256)*B + 128; \tag{3.2}$$

$$Cr = (131/256)*R \quad (110/256)*G \quad (21/256)*B + 128; \tag{3.3}$$

2)The Cr of the eye region is smaller than the other in Cr color space . So Cr is transformed with Cr=255-Cr. After it is transformed, the Cr of the eye region is larger than the other in Cr color space in the input face,wee have taken.
3)From the above Cr component of the image extract only those regions which are greater than a threshold. 4)Find the edges in the eye region extracted from above.
5)Now initially detect the ellipses in the extracted eye region.
Now,in the sections to follow,the algorithm to extract the ellipse from the eye region.

3.1 Line Detection

An edge in a image is a line segment:y=mx+c;m=slope,c=intercept. m and c are enough to describe a line.Mapping from spatial domain to parametric domain is done.

Case 1: y=m1x+c1straight line in xy plane.c1=y-m1x.A line in xy plane gets mapped to a single point in mc plane.
Case 2: We have a single point (x1,y1) in the xy plane.Then,if y=mx+c has(x1,y1); y1=mx1+c.
We can have many straight lines passing through (x1,y1)..for each of these straight lines values of m and c will be different.

$$c = -mx_1 + y_1. \qquad (3.1.1)$$

x1,y1 constants c,m are variables.
If we map x1,y1 in the mc plane,c=-mx1+y1is equation of a straight line.
2 points in x,y plane (xi,yi),(xj,yj).A line going through the above points y=mx+c.
2 pts in xy plane mapped to 2 different lines in parametric space.Point at which lines meet gives us m and c.

Line Detection In An Image

1)mc space is divided into number of accumulator cells .(A);m(min) and m(max):expected range of slopes in a particular application.
2)Initialize each of accumulator cells to 0;A(i,j)=0 (3.1.2)
3)(xi,yi):set of points;mc:2Darray of accumulator cells.
4)(xk,yk) in spatial domain;c=-mxk+yk.. (3.1.3)
equation of line.Compute c while varying m and m while varying c.
5)c=-mxk+yk.Perform A(i,j)=A(i,j)+1.for all points.
6)If at the end A(i,j)=Q ;

$$Q \geq threshold$$

Then declare that particular line with corresponding m and c as a line.

Problem : If the line is parallel to x axis, slope is infinity
Solution : Normal representation of a line. Parameters are rho and theta.

$$\rho = x_1 cos\theta + y_1 cos\theta \qquad (3.1.4)$$

Particular point in spatial domain is mapped to a sinusoidal curve in rho theta plane.
Q collinear pts in xy plane mapped to Q sinusoidal curves in rho theta plane.

1)All the sinusoidal curves will intersect at a single point, which gives corresponding rho and theta.
2)rho and theta for the line passing through the above points.
3)Allow theta to assume values and solve for corresponding values of rho.Similarly,calculate rho by varying theta.

3.2 Circle Detection

Equation of a circle where,(h,k) is the center and r is radius of the circle.

Algorithm:

1)Construct a 3D accumulator array with dimensions h,k,r(here,parameters are h,k and r).
2)Since we know the values h and k assume,we fix h and k and find the coressponding radius.
3)In this way,we accumulate the scores of each circle in the accumulator.
4)If Q is greater than or equal to threshold,we declare it to be a circle.

3.3 Ellipse Detection with Randomized Hough Transform

1. A pixel in the image is transformed into a parameterized curve.
2. valid curves parameters are binned into an accumulator where the number of curves in a bin equals its score.
3. A curve with a maximum score is selected from the accumulator to represent a curve in the image.

Algorithm:

```
While(we find ellipses OR not reached the maximum epoch)

    for(a fixed number of iterations)

        Find a potential ellipse.

            If (the ellipse is similar to an ellipse in the accumulator),average the two ellipses and replace the one in the accumulator.Add 1 to the score.
            Else insert the ellipse into an empty position in the accumulator with a score of 1.

            End if

        Select the ellipse with the best score and save it in a best ellipse table.

            End for
Remove the best ellipses's pixels from the image Clear the accumulator.
            End while
```

Algorithm Description:

Ellipse Equation:

$$A(x-p^2)+2B(x-p)(y-q)+C(y-q)^2=1 \tag{3.3.1}$$

with restriction

$$B^2 \leq 4AC \tag{3.3.2}$$

where,(p,q) is the center of the ellipse
2*a and 2*b are major and minor axes of the ellipse respectively.
We use (p,q,a,b) in the algorithm.

Determining Ellipse Center:

1) Select three points randomly X1,X2, and X3.(Range:from 1 to length of image.)
2)Determine the equation of the line for each point where the lines slope is the gradient at that point: y = mx+b.
3) Determine the intersection of the tangents passing through point pairs (X1,X2) and (X2,X3)
The tangent intersection points t12 and t23 are found by solving

$$\begin{pmatrix} m_1x+b_1-y=0 \\ m_2x+b_2-y=0 \end{pmatrix} \tag{3.3.3}$$

and

$$\begin{pmatrix} m_2x+b_2-y=0 \\ m_3x+b_3-y=0 \end{pmatrix} \tag{3.3.4}$$

4)Calculate the bisector of the tangent intersection points.

This is a line from the tangents intersection, t, to the midpoint of the two points, m.
5)The midpoint coordinate and bisection n coordinate t12 are used to get the bisection line equation.
6) Find the bisectors intersection to give the ellipses center, O.Ellipse center located at (x,y) derived from:

$$\begin{pmatrix} m_1x + b_1 - y = 0 \\ m_2x + b_2 - y = 0 \end{pmatrix} \tag{3.3.5}$$

7) Determining semimajor a and semiminor axis b: center (p,q) ,a,b can be found.
Ellipse equation is:

$$A(x - p^2) + 2B(x - p)(y - q) + C(y - q)^2 = 1 \tag{3.3.6}$$

After substituting (p,q) in the above equation,it reduces to

$$Ax^2 + 2Bxy + Cy^2 = 1 \tag{3.3.7}$$

For the 3 points,X1,X2,X3:

$$\begin{bmatrix} Ax_1^2 + 2Bx_1y_1 + By_1^2 = 1 \\ Ax_2^2 + 2Bx_2y_2 + By_2^2 = 1 \\ Ax_3^2 + 2Bx_3y_3 + By_3^2 = 1 \end{bmatrix} \tag{3.3.8}$$

$$semi - majoraxisa = \sqrt{1/A} \tag{3.3.9}$$

$$semi - majoraxisb = \sqrt{1/C} \tag{3.3.10}$$

Verifying whether the Ellipse Exists in the Image

1)Even though at this point the ellipse parameters (p,q,a,b,c) were found it is possible the ellipse does not exist in the image. Equation of a conic:

$$Ax_2 + 2Bxy + Cy_2 + Dx + Ey + F = 0 \qquad (3.3.11)$$

2)If

$$4 * a * c - b.^2 > 0 \qquad (3.3.12)$$

Ellipse or Circle,= 0 Parabola and if less than 0 then,it is a Hyperbola.
3)Even though the ellipse equation is satisfied as we see from figure ,it is possible the ellipse does not have enough pixels in the image.
4)To determine if the ellipse exists in the image the equation of the ellipse is used to generate points in the image on the perimeter to the ellipse. The number of points generated is equal to the circumference of the ellipse, which is found with the equation:
5)These points are used to generate a mask of the ellipse, which is anded with the image. The number of pixels in the new image are counted and divided by the circumference of the ellipse. This yields a ratio of pixels and the circumference. If the ratio is greater than a threshold specified by the user the ellipse exists in the image. At this stage the ellipses parameters were found and it was verified to exist in the image. Now the ellipse is added to the accumulator. The accumulator stores the (p,q,a,b, score) of an ellipse.Ellipse points are generated by solving the following equations for

$$\phi = 0 \quad to \quad 2\Pi \qquad (3.3.13)$$

$$x = acos\phi \qquad (3.3.14)$$

$$y = bsin\phi \qquad (3.3.15)$$

6)The number of points generated are equal to the number of values used between [0 and 2*pi], in this algorithm the number of values generated is equal to the circumference of the ellipse.

7)The following three steps occur to accumulate a new ellipses center coordinates (p,q), semimajor axis a, and semiminor axis b.If the diatance between the new ellipse center is within a threshold.

$$\sqrt{(p_i - p)^2 + (q_i - q)^2} > threshold \qquad (3.3.16)$$

$$\text{mod } (a_i - a) > semi - majoraxisthreshold \qquad (3.3.17)$$

$$\text{mod } (b_i - b) > semi - majoraxisthreshold \qquad (3.3.18)$$

8)For any ellipse in the accumulator where the above conditions hold, perform a weighted average between each of the ellipse parameters (use the score as the weight) and replace the ellipse in the accumulator with the new weighted ellipse, then increase the score for this ellipse by one. Example weighted average of semimajor axis length:

$$\frac{(a_i * score + a)}{(score + 1)} \qquad (3.3.19)$$

Chapter 4

Proposed Work

Using Template Matching method,we match the eye region in the given input face.After finding the best match in the image,we fit an ellipse to the eye using the Hough Transform.We fit a rectangle to the region.Then,we calculate two corners(diagonally opposite) of the rectangle and approximate those corners to be the corners of the eye.We use correlation. Correlation is a measure of the degree to which two variables agree, not necessary in actual value but in general behavior. The two variables are the corresponding pixel values in template and source.Correlation can be found out by the formula:

$$cor = \frac{\sum_{i=0}^{N-1}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=0}^{N-1}(x_i - \bar{x})^2(y_i - \bar{y})^2}} \qquad (4.1)$$

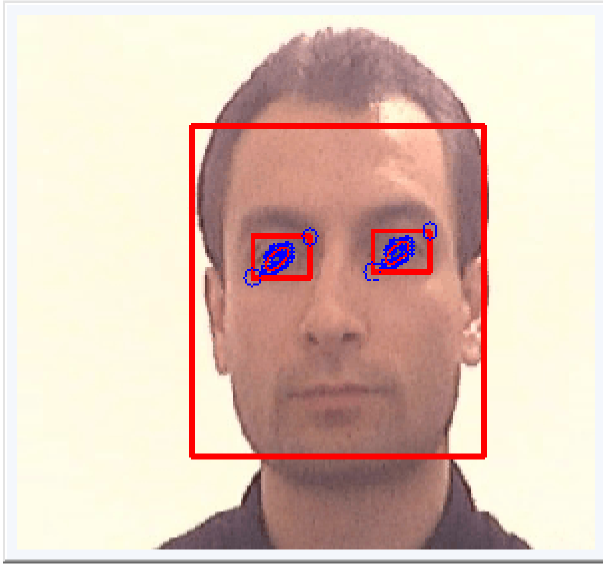
x is the template gray level image
x is the average grey level in the template image
y is the source image
y is the average grey level in the source image
N is the number of pixels in the section image
(N= template image size = columns * rows)
The value cor is between 1 and +1, with larger values representing a stronger relationship between the two images.

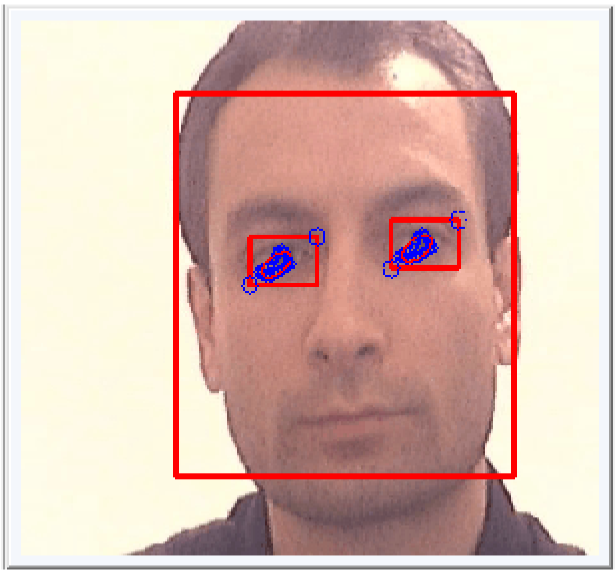
Correlation Values

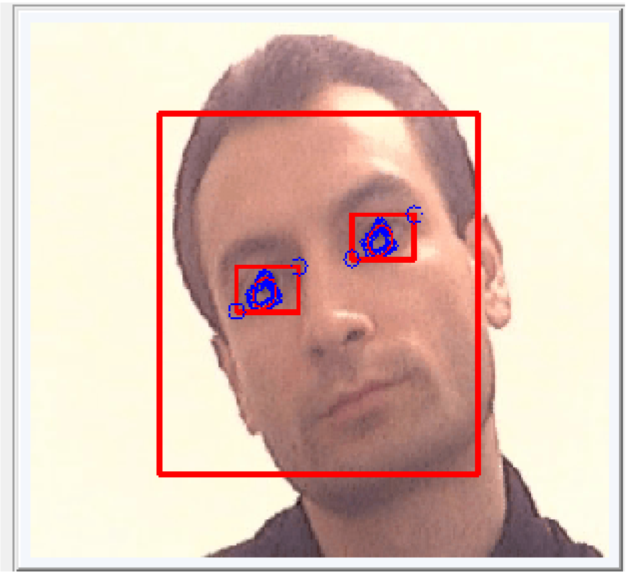
A zero correlation implies that,there is no relation between the variables.For a perfect positive correlation,the correlation value is +1.For a perfect negative correlation,the correlation value is -1.

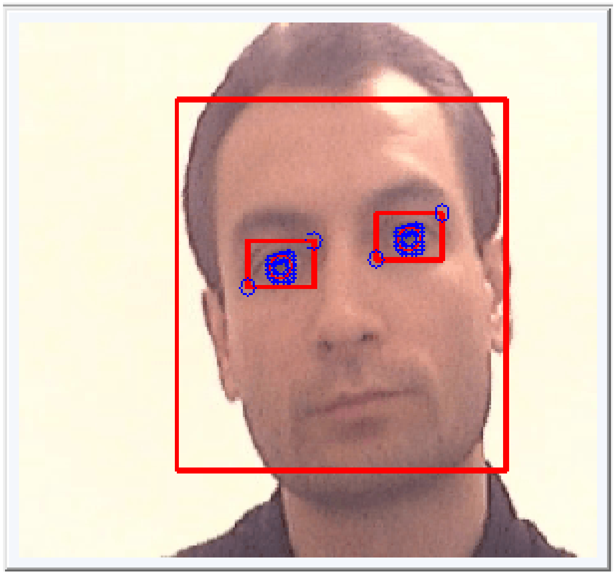
Chapter 5

Simulation Results









Chapter 6

Conclusion

Interest point detection algorithms were discussed initially. Algorithms discussed were Harris Corner Detector ,Sobel interest Point Detector, Prewitt Interest Point Detector,Shi Tomasi Corner detector,Roberts Cross Edge Detector. After that,eye corner detection methods were discussed. Line detection,circle detection and ellipse shape detection algorithms were discussed.The simulation results were also shown in the above section.

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