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Analysis of Statistical Properties of Eye Lens Images to Detect Cataract at Earlier Stage

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ABSTRACT

Cataract is clouding of eye lens cause partial or complete blindness. Aging of eye lens or injury to eye lens are major reasons to cause cataract. Smoking and use of excessive use of steroids also leads to development of cataract. Clumping of protein molecules and water molecules in natural eye lens leads of development of Cataract. Opacity at center of lens it is called as nuclear cataract while at edges of lens is called cortical cataract. The lens focuses the reflections form object at retina and causes clear vision. The opaqueness of lens at center position due to nuclear cataract causes the incorrect image formation at retina causing poor vision. Detection of same at earlier stage may help to correct vision by us of external lens. The patient may be advised treatment to prohibit the further growth of cataract. In research work presented slit lamp images with image processing techniques are used to detect the cataract at earlier stage. The wide slit illumination images are used to detect cataract. In the proposed system Hough circle detection transform is preferred to extract lens structure. The mask is created using lens center and radius extracted from Hough circle detection transform. The lens without cataract is having less mean value and uniformity compared to lens wit cataract. These statistical parameters are independent on scale and size of image. The graphical user interface is developed to automate and to make system access user friendly.

Keywords: *cataract, slit lamp images Lens extraction, Hough circle transform, statistical parameters*

1. Introduction

Cataract causes partial blindness at early stage. It may leads to complete blindness in mature stages. Cataract due to aging of eye lens is more common. The nuclear cataract builds at center of lens structure and grows towards outer rim of eye lens while in cortical cataract occurs at outer rim and grows to center. Most of cases the blindness after age of 40 is due to cataract. It is becoming very serious issue for most of world health organizations as it is observed in minor edge children too. Most of animals are also suffering from cataract. The issues are very serious in most of developing countries where number of ophthalmologists is less compared to human population. As well the awareness amongst people is less about this disease. The eye lens surgery is only remedy which is for replacing the original lens with synthetic lens. The mature cataract is very serious and leads to complete blindness and it may leads to loss of eye vision though out of life.

Ophthalmologist are using slit lamp for observation of cataract. The cataract images can be acquired using slit lamp images and processed using image processing technique to detect at earlier stage.

The color based segmentation or segmentation based on intensity spread are most popular in detection of cataract. Correct lens localization may leads to accurate detection of cataract. The proposed method use comparisons of statistical parameters to detect intensity spread in lens structure and detect the severity of cataract.

2. Relevant research regarding cataract

The correctness and success of computer added cataract detection method is based on accuracy of pupil segmentation, feature extraction and grade prediction. The cataract can be detected at earlier stages by analysis of variation of intensity patterns in lens structure. [1-4]. The model based approach is suggested by the J.Nayak for lens localization while he has suggested the support vector based categorization[5]. Y. Xu et. al, [6] has suggested automatic grading approach to grade cortical and Posterior Sub-Capsular (PSC) cataract while low level vision features are used to characterize photometric appearances and geometric structures in retro illuminated images. X. Gao et. al, [7] et. al, have introduced group sparsity-based constraint for linear regression, which performs feature selection, parameter selection and regression model training simultaneously for detection and categorization. R. Supriyanti et.al, [8,9] used specular reflection appearance, texture uniformity and average intensity inside the pupil as cataract detection features. W. Huang et.al, [10] has used neighboring labeled images in a ranked image list, which is achieved using a learned ranking function for grading of nuclear cataract in a slit-lamp image. The ranking function is learned via direct optimization on a newly proposed approximation to a ranking evaluation measure.

3. Methodology

The image processing algorithm is developed to detect the cataract using lens localization technique and extracted statistical parameters of lens image. The eye images are acquired using slit lamp mounted camera and processed. From review it is observed that the success of detection of any image processing method depends on the correct and fast localization of lens structure. The lens structure is circular in shape and its color and texture reflects severity of cataract. The lens without cataract is black in color and has mean intensity threshold below 147 for grayscale images with 8 bit resolution.

The color based segmentations are popular. But in case of immature and cataract at early stages the detection is hard using color based segmentation. The circular shape of lens encourages the researches to use transform based segmentations. Hough circle detection transform is widely preferred in iris detection and extraction of iris.

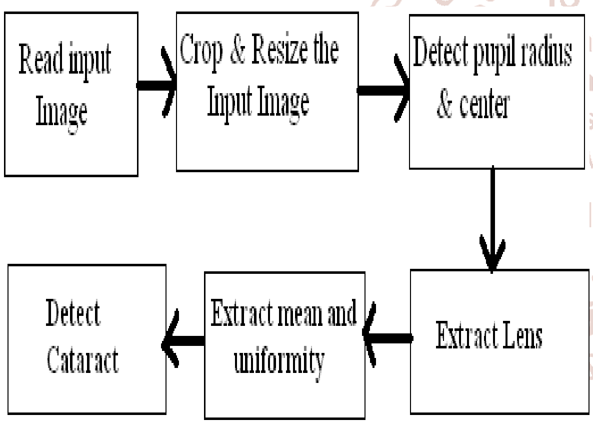

Figure 1 Flow graph for lens localization and feature extraction

In proposed method the Hough circle detection transform is used to extract the lens from eye structure. The transform transfers the image from the image space to the parametric space. The accumulator is used to count number of circles passing though given point. The algorithm uses iterative procedure to increment the radius of the circle and store the results. The computational overheads can be reduced by detecting the circle over predefined radius range.

Hough circle detection transform returns the center and radius matrix of detected circles. The success of method depends on the detection of only one pupil circle. For same the image is cropped and resized to 120 X 120 pixels to adjust lens radius within range of 60 to 65 pixels range. The extracted pupil center and radius is used to segment the lens structure from eye image. The mean intensity value of the extracted lens without cataract is below 147 and uniformity is below 0.5. These values are much higher for lens with cataract.

4.1 Input image Pre processing

Let $I(x,y)$ is the input color eye image acquired using slit lamp in RGB format with 24 bit resolution per pixel.

$$gi(x,y) = 0.298 I_r(x,y) + 0.587 I(x,y) + 0.11 I(x,y) \qquad \text{............(1)}$$

Where $gi(x,y)$ is gray scale image and $I_g(x,y)$, $I_r(x,y)$ and $I_b(x,y)$ are green, red and blue planes.

The input gray scale image is cropped and resized to 120×120 pixels. It is assumed that the cropped image $z(x,y)$ is containing circular lens and no complete iris.

Such that

$$z(x,y) \in gi(x,y) \text{........................(2)}$$

4.2 Lens localization using Hough circle detection transform

It is assumed that the lens radius is within range of 50 to 65 pixels as image is preprocessed and cropped such that lens radius is within range of 60 to 65. The parameters used in Hough circle detection transform for lower and higher radius range are as below.

$$r_1 = 50, r_2 = 65$$

The Hough transform for circle detection is applied to detect the pupil in image $z(x,y)$ to find out pupil center and radius.

The characteristic equation of circle is given by:

$$(X-a)^2 + (Y-b)^2 = r^2 \text{...........(3)}$$

Where (a, b) is center of circle and r is radius of circle
The circle can be described by two equations:

$$x = a + r\cos(\theta) \text{......................(4)}$$

$$y = b + r\sin(\theta) \text{......................(5)}$$

Thus the role of hough transform is to search for the triplet of parameters (a,b,r) which determines the points (X_i, Y_i). The conversion of image into parametric domain is as show in figure 2 displayed below.

Let $gi(x,y)$ is the gray scale image obtained from color image $I(x,y)$.

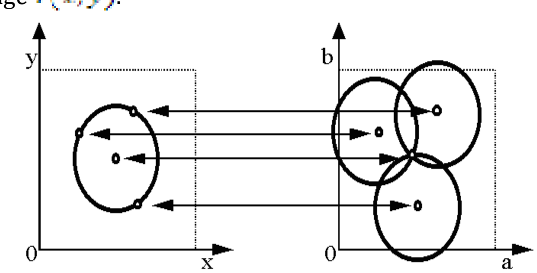

Figure2. Hough transformation from spatial domain to parametric domain

Let $z1(x,y)$ is binary image obtained from input gray scale image $gi(x,y)$.

For given values of $r1$ and $r2$ let $c(a,b,r)$ is the three dimensional vector representing the circle parameters where a, b represents the center of circle and r represents radius.

Let i and j are row and column values if input image $z1(x,y)$.

$r - ((x_i - a)^2 - (y_i - b))^2 = 0$ then

$c(a,b,r) = c(a,b,r) + 1$ for all

$r \in (r_1 < r < r_2)$......(6)

The pupil center and radius is given by $c_1(a,b,r)$ such that $c_1(a,b,r) = max(c(a,b,r))$............(7)

The lens extracted using Hough circle detection algorithm is as displayed in figure 3.

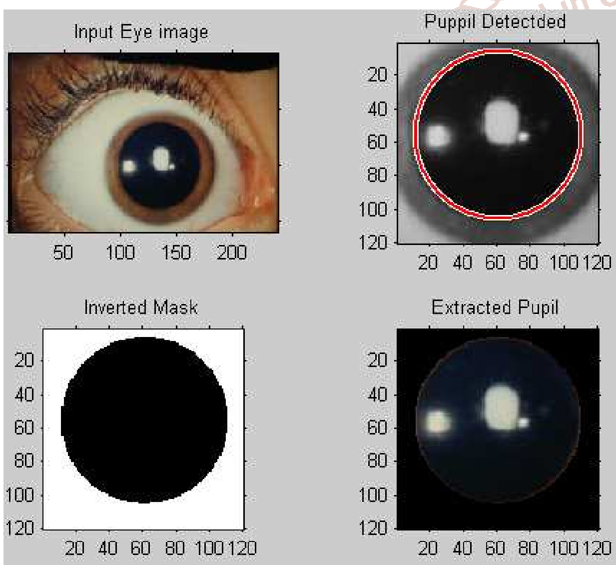

Figure3. Lens extracted from slit lamp eye image without cataractThe image displays the original image, lens detected, mask for detected lens and extracted lens.

4.3 Statistical feature extraction:

Let $z_2(x,y)$ is the extracted lens structure from the eye image $gi(x,y)$ using $c_1(a,b,r)$. The statistical parameters such as mean, homogeneity and smoothness extracted lens are calculated.

$$\text{Mean} = \sum_{i,j} x(i,j)\,p(i,j) \text{.......} \qquad (8)$$

$$\text{Homogeneity} = \sum_{i,j} \frac{p(i,j)}{1 + |i-j|} \text{..........}(9)$$

$$\text{Smoothness} = 1 - \frac{1}{1 + \sum_{i,j} x(i,j)} \text{......}(10)$$

The mean homogeneity and smoothness are calculated and compared with these parameters of lens without cataract.

5. Result discussions

The eye images of 400 volunteers with and without cataract are obtained. The features are calculated and compared. The results are communicated to ophthalmologist and verified from them. The result of ten sample images is displayed as shown in the table below. The proposed systems output and ophthalmologist is compared. It is observed that the results obtained from proposed cataract detection system are correct.

Table No. 5.1 Comparison of system results with results of ophthalmologists

Image No.	Systems Output	Doctors opinion
Img001	No	Healthy / N
Img002	Yes	early / Y
Img003	Yes	Nuclear / Y
Img004	Yes	Nuclear /Y
Img005	Yes	mature / Y
Img006	No	Healthy / N
Img007	No	Cortical / Y
Img008	Yes	Nuclear/ Y
Img009	Yes	early/ Y
Img010	Yes	early / Y

Table 2 indicates the confusion matrix generated to calculate sensitivity, specificity and accuracy obtained.

Table 2: Confusion matrix and results for Hough Circle Detection transform and correlation

	Predicted Cataract by proposed algorithm		
Actual observation		Yes	No
	Yes	200	40
	No	60	100

Total Number of Images	Cataract Affected	Sensitivity	Specificity	Accuracy
400	240	75	62.25	83.33

The accuracy indicated by above method is 83.33% for set of 400 images.

The GUI for detection of cataract has been developed using MATLAB. The images obtained from government hospital Pandharpur have been processed using Hough circle detection transform and correlation. The result of cataract detection of eye without cataract is as displayed in figure 3.

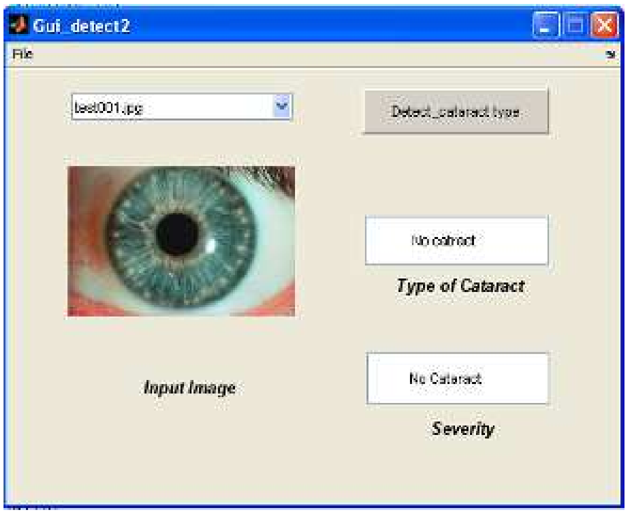

Figure 3 Detection for eye without cataract

6. Conclusion

Cataract causes lens opacity which leads to partial or complete blindness. The automated image processing techniques can be used to develop system to detect the cataract at earlier stage and help ophthalmologist to minimize inter grader and intra-grader errors. The Hough circle detection transform used is accurate to detect the lens structure gives lens radius and centers used for lens extraction. The statistical parameters like mean, homogeneity and smoothness are used to differentiate lens with cataract and without cataract. The cataract detection accuracy is 83.33%.

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