Estimating Severity of Nuclear cataract Using slit Lamp Images

[1]A.B. Jagadale, [2]Dr. S.S.Sonavane, [3]Dr. D.V.Jadhav

[1]Ph.D. Research Scholar SPPU, [2]Director DYPTC Pune, [3] Joint Director DTE Maharashtra

[1]Department of E&TC, JSPM's RSCOE Tathwade

[1]Pune, India

1. **Abstract-**The nuclear cataract is one of cataract type cause partial or complete blindness. It may cause due to aging of eye lens or due to injury to eye lens. Smoking and use of excessive use of steroids may leads to development of cataract. The clouding of eye lens due to clumping of protein molecules and water molecules together leads of development of Cataract. If it starts developing at center of lens it is called as nuclear cataract. The lens focuses the viewed image 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 using external lens. The patient may take treatment to prohibit the further growth of cataract. Slit lamp images with image processing techniques can be 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 used to extract lens structure. The mask are created using parameters extracted from hough transform. The correlation of mask and extracted lens is taken to detect type and severity of cataract. The graphical user interface is created to automate and to make access simple.

***Key words:** nuclear cataract, Lens extraction, Hough circle transform, correlation*

2. Introduction

Cataract cause partial blindness at initial stages. It may leads to complete blindness in mature stages. Cataract due to aging is more common. The nuclear cataract builds at center of lens structure and grows towards outer rim of eye lens. Most of the vision problems after age of 40 are 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 correlation technique to study intensity spread in lens structure to detect the severity of cataract.

3. 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.

4. Methodology

The popular image processing techniques can be used to detect the cataract type and its grade. The images are obtained using slit lamp mounted camera and processed to detect the cataract. From review it is observed that the success of detection of any image processing method depends on the accurate segmentation of lens structure. The lens is circular in shape and its color is depends on types and severity of cataract. As well the lens without cataract is black in color.

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 used in iris detection and extraction of iris.

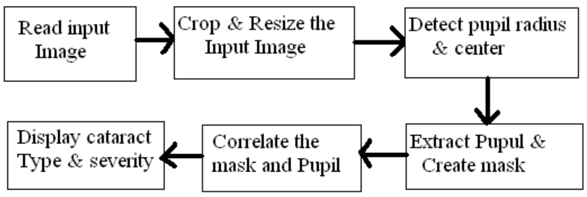

Figure 1 Flow graph for lens localization using Hough circle detection Transform

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 gives 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 get pupil within predefined range. The extracted pupil center and radius is used to segment the lens structure from eye image. It is also used to create mask for detect the type of cataract. The correlation between extracted lens structure and the mask used to detect type and severity of cataract.

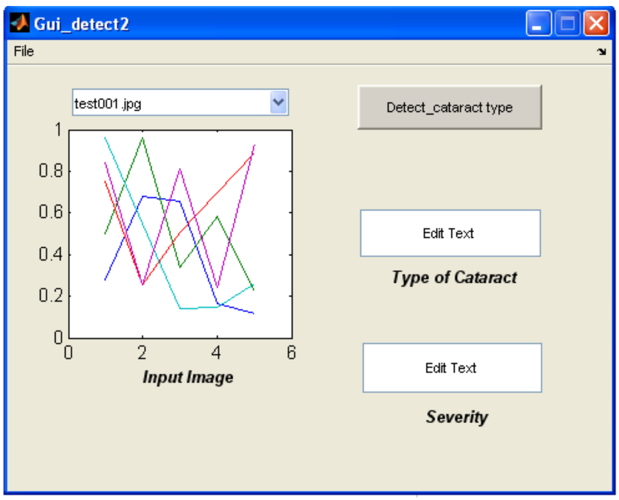

Figure 2. MATLAB GUI to detect cataract

The GUI has been developed using MATLAB to detect different types of cataract using slit-lamp images. The hough circle detection transform and correlation is used for lens localization and percentage of cataract with respect to rest of eye portion.

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.

$$gi(x,y) = 0.298 I_r(x,y) + 0.587 I(x,y) + 0.11 I(x,y) \ldots\ldots\ldots\ldots(1)$$

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 pupil and part of iris.

Such that

$$z(x,y) \in gi(x,y) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

4.2 Lens localization using Hough circle detection transform

The lens is circular in shape and can be easily detected using hough circle detection transform. It is assumed that the lens radius is within range of 60 to 65 pixels as image is preprocessed and cropped.

$$r_1 = 60, r_2 = 65$$

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:

$$(X-a)^2 + (Y-b)^2 = r^2 \ldots\ldots\ldots\ldots(3)$$

Where (a, b) is center of circle and r is radius of circle

The circle can be described by two equations:

$$x = a + r\cos(\theta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$y = b + r\sin(\theta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

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)

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

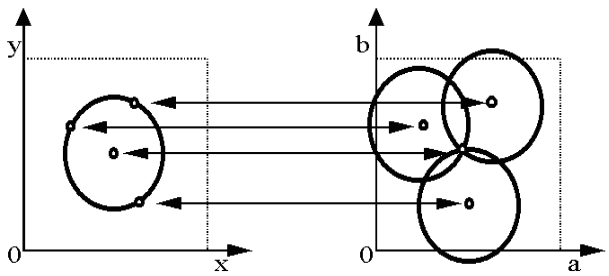

Figure 3. Hough transformation from spatial domain to parametric domain

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 circles are the transformed to parametric domain as show in figure below.

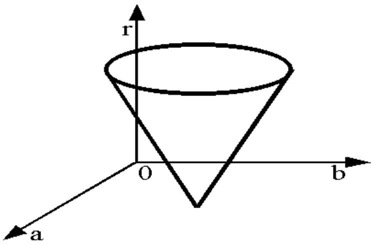

Figure 4. Circle representation in parametric domain (a,b,r)

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)

4.3 Cataract detection and categorization:

Let $z_2(x,y)$ is the extracted lens structure from the eye image $gi(x,y)$ using $c_1(a,b,r)$ and $m_1(x,y)$, $m_2(x,y)$ are binary mask images of same size for nuclear and cortical cataract.

$Let\ m_1(x,y)=1\ for\ ((x_i-a)^2-(y_i-b)^2) < r_x,\ \ r_x \in (0 < r_x < r_y)$……(8)

$Let\ m_2(x,y)=1\ for\ ((x_i-a)^2-(y_i-b)^2) < r_y,\ \ r_y \in (r_x < r_y < r)$……..(9)

Let $z_3(x,y)$ is binary image obtained from $z_2(x,y)$

$z_3(x,y)=1\ for\ \ z_2(x,y) \geq th$ …………(10)

$z_3(x,y)=0\ for\ \ z_2(x,y) < th,\ \ th = mean(\ z_2(x,y))$ ……….(11)

The 2-D correlation is taken between input binary image $z_3(x,y)$and mask $m_1(x,y)$ and $m_2(x,y)$

$$r1 = \frac{\sum_m \sum_n (z3_{mn}-\overline{z3})(m1_{mn}-\overline{m1})}{\sqrt{\left[\sum_m \sum_n (z3_{mn}-\overline{z3})\right]^2 \left[\sum_m \sum_n (m1_{mn}-\overline{m1})\right]^2}}$$ ……(12)

where $\overline{z3} = \text{mean2}(z)$, and $\overline{m1} = \text{mean2}(m1)$.

$$r2 = \frac{\sum_m \sum_n (z3_{mn}-\overline{z3})(m2_{mn}-\overline{m2})}{\sqrt{\left[\sum_m \sum_n (z3_{mn}-\overline{z3})\right]^2 \left[\sum_m \sum_n (m2_{mn}-\overline{m2})\right]^2}}$$ ……(13)

where $\overline{z3} = \text{mean2}(z3)$, and $\overline{m2} = \text{mean2}(m2)$.

Here r_1, r_2 are correlation values and r is predefined value.

Cataract is detected for $(r_1 > r)\ |(r_2 > r) = 1,\ \ 0 < r < 1)$.

Cataract is nuclear for $(r_1 > r_2)$.

Cataract is cortical for $(r_1 < r_2)$.

5. Result discussion

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 5.

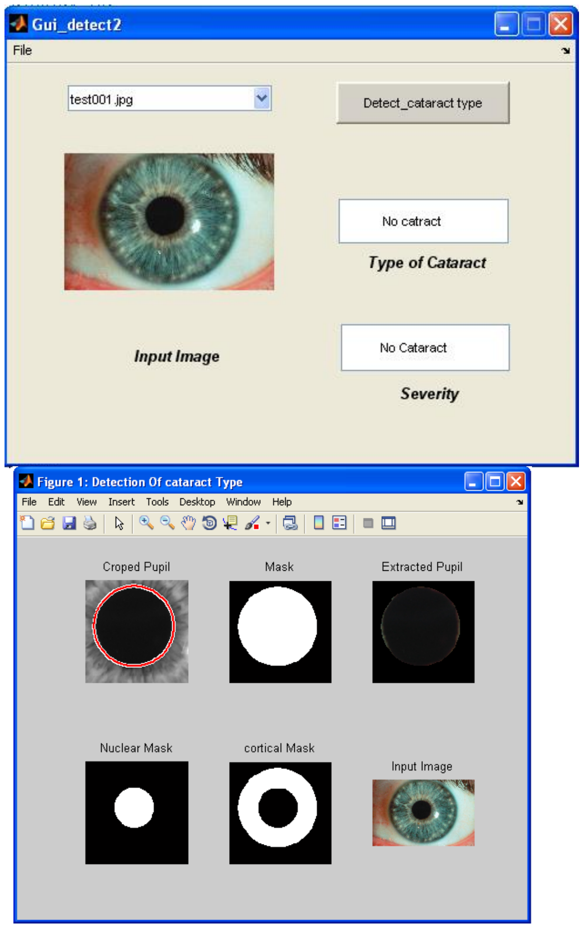

Figure 5 Detection for eye without cataract

The result of nuclear cataract is as in figure 6. It is observed that the cataract stars developing at center of the lens and grows toward the outer edge of lens.

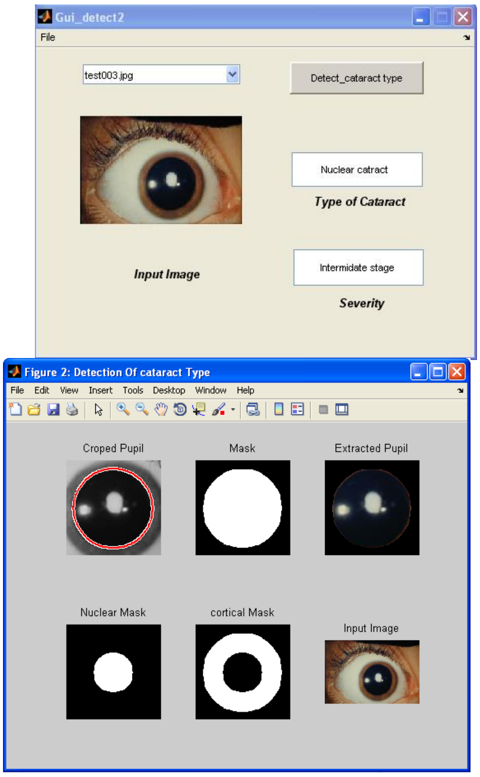

Figure 6 Detection of Nuclear Cataract

The database of image obtained from government hospital Pandharpur has been used for detection of various types cataract of 150 patients is used. 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.

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

Table No. 5.1 Result comparison of method using hough transform and correlation

6. Conclusion

Cataract can cause partial or complete blindness. The detection of cataract at earlier stage can help patient to extend the life of original natural lens. The medicines can be suggested to minimize the growth of cataract. The 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. Correlation between mask and extracted lens structure used to detect severity of disease as coresults are mapped between 0 and 1.

7. References

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