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Cost-Effective Mobile Cataract Detection System

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Abstract - *Cataract is one of the most prevailing causes of visual disability in the world. A gradual development of protein layer on eye lens over a certain period of time makes it white and cloudy. It thereby causes blurry vision that can lead to partial or permanent blindness. Beforehand treatment can reduce the adversities faced by cataract patient and avoid blindness. People living in underdeveloped countries and rural areas cannot get effective treatment in time due to scarcity of eye care services and resources. Also the being used methods of cataract diagnosis are complex and costly. So there is a need of cost effective and simple process of cataract detection. Also transportation and portability of equipment are important factor in diagnosis of such a ruinous disease. Hence we have made a noble attempt of putting forth a cost effective and simple cataract diagnosis method.*

Key Words: Cataract, Gray scale, Circular Hough Transform, Canny edge, Android app.

1. INTRODUCTION

The human eye consists of different parts like pupil, retina, choroid, lenses, etc. Each of them performs specific functions which helps to get a clear vision of an object. In cataract, the lens gets clouded which leads to blurred vision, which can later on cause blindness gradually [1]. Hypertension, diabetes, hormonal factors, etc. can be some of the causes of cataract. Accurate and timely diagnosis of cataract is needed so as to prevent vision loss. Cataract can be of three types named as cortical cataract, nuclear cataract and posterior sub-capsular cataract. These are classified according to the region of the eye where cataract is present. Cortical cataract occurs at edge of lens and moves towards the center like spokes of wheel. Nuclear cataract forms at enter of lens called as nucleus and then spreads out to other part of lens. Posterior sub-capsular cataract occurs on back of lens.

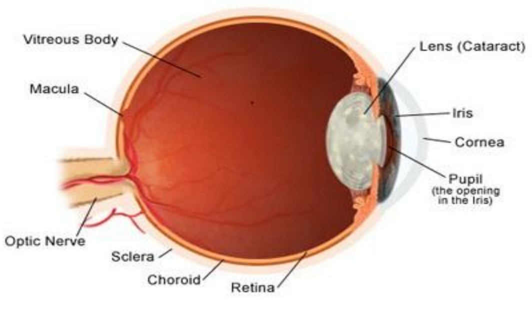


Fig -1: Development of Cataract

Till date, slit lamp images and fundus camera have been used for cataract detection. Multiple methods such as red reflex method and light scattering methods are used for eye examination. In red reflex method examiner puts a dilating drop in patients eyes and places it before opthalmoscope for detection. In dynamic light scattering method a DSL probe is used along with keratometer for cataract detection. Both the given methods require heavy and mostly non portable equipment. Thus it incurs large cost of equipment and transportation. Also it is very costly and unaffordable to rural people.

The proposed system tries to overcome all these problems. This system determines whether a person has cataract or not and after the detection, gradation of the cataract is done according to its severity. A simple android application of the given system is installed in an android mobile phone with a camera. It provides a great alternative to cataract detection. We do not mean to replace the professional system of cataract diagnosis. It's just an approach to minimize the cost and time of cataract detection in the remote places where advanced medical help and resource support is in scarce.

2. PROPOSED METHOD

2.1 Mathematical Model

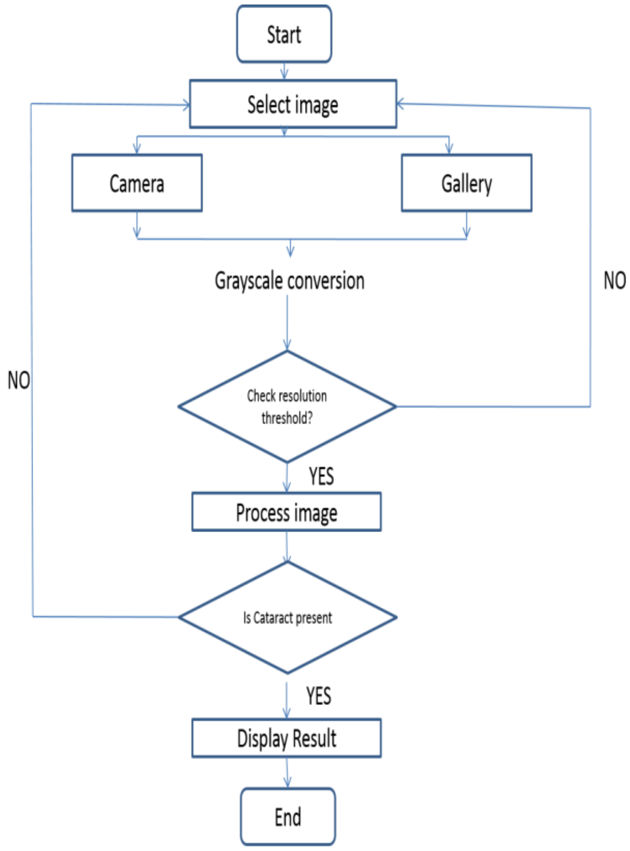
System S= Cataract detection system

System S= {I, G, F, R, D, C}
where,
I= Images taken from camera or databases
G= Grey scale transformation of image

F= Functions used = {GP, CHT, CED}
where,
GP= Grey projection algorithm function
CED= Canny-edge Detection
CHT= Circular Hough transform function

R= Result to be displayed= {Y, N}
Y= cataract detected
N= cataract not found
D= Search for doctors using GPS.
C= Constraints
where, c1= bad image
c2= battery

2.2 Process Flow-Chart



2.2 Methods Implemented

2.2.1 Gray Scale Conversion

Gray scale conversion is done by two methods:

1. Average Method
2. Luminosity Method

1. Average Method:

In average method we just take the average of RGB colors.

$$Grayscale = ((R+G+B)/3)$$

The image obtained by this method is rather blackish than grayscale image. The reason behind this is the wavelengths of these colors. Every color have different wavelength and image is formed by contribution of each color. Here all three colors have equal contribution of 33%. Thus it leads to blackish image.

2. Luminosity Method:

We have to take the contribution of colors according to their wavelengths. Since red color having more wavelength than all three its contribution must be less and increase contribution of green color. The contribution of blue must be placed between these two colors.

$$\text{Gray-scale image} = ((0.3 * R) + (0.59 * G) + (0.11 * B))$$

According to this equation, Red has contribute 30%, Green has contributed 59% which is greater in all three colors and Blue has contributed 11%. Hence we get a proper gray-scale image.

2.2.2 Gray Projection

The gray projection algorithm, bases on the principle of statistics which accumulates each pixel by row or column in gray scales. The process is described as follows [3,9,11]. Given a $M \times N$ gray image $I(i,j)$, which denotes the gray scale of the pixel with the coordinates (i,j), the horizontal and vertical gray projection can be defined as,

$$H(i) = \frac{\sum_{j=0}^{N-1} I(i,j)}{N} \qquad V(j) = \frac{\sum_{i=0}^{M-1} I(i,j)}{M}$$

2.2.3 Circular Hough Transform

The Hough transform can be described as a transformation of a point in the x-y plane to the parameter space. The parameter space is defined according to the shape of the object of interest.
A straight line passing through the points (x_1, y_1) and (x_2, y_2) can be described in the x-y plan by:

$$y = ax + b$$

This is the equation for a straight line in the Cartesian coordinate system, where a and b represent the parameters of the line. The Hough transform for lines does not using this representation of lines, since lines perpendicular to the x-axis will have an a-value of infinity. This will force the parameter space a, b to have infinite size. Instead a line is represented by its normal, which can be represented by an angel θ and a length ρ .

$$\rho = x.\cos(\theta) + y.\sin(\theta)$$

The parameter space can now be spanned by θ and ρ , where θ will have a finite size, depending on the resolution used for θ . The distance to the line ρ will have a maximum size of two times the diagonal length of the image. The circle is actually simpler to represent in parameter space, compared to the line, since the parameters of the circle can be directly transfer to the parameter space. The equation of a circle is:

$$r^2 = (x - a)^2 + (y - b)^2$$

As it can be seen the circle got three parameters, r, a and b. Where a and b are the center of the circle in the x and y direction respectively and where r is the radius. The parametric representation of the circle is:

$$x = a + r.\cos(\theta) \qquad y = b + r.\sin(\theta)$$

Thus, the parameter space for a circle will belong to R^3, whereas the line only belonged to R^2. As the dimension of the parameter space R increases so the complexities of the Hough transform increase. In order to simplify the parametric representation of the circle, the radius can be held as a constant or limited to number of known radii.

To finding circles in an image using CHT, First we find all edges in the image. At each edge point, we draw a circle. This circle is drawn in the parameter space, such that our x axis is the a-value and the y axis is 557 the b-value while the z axis is the radii. At the coordinates, which belong to the perimeter of the drawn circle, the value in the accumulator matrix will be increased. The accumulator will now contain numbers corresponding to the number of circles passing through the individual coordinates. Thus the highest numbers (selected in an intelligent way, in relation to the radius) correspond to the centre of the circles in the image. The algorithm for Circular Hough Transformation can be summarized to:

a. Find Hough edges. Then for each edge point //HOUGH BEGIN
b. Draw a circle with the center in the edge pont with radius r and increment all co-ordinates that the perimeter of the circle passes through in the accumulator.
c. Find one or several maxima in the accumulator. //HOUGH END
d. Map the fund parameters (r,a,b) corresponding to the maxima black to original image.

2.2.3 Canny Edge Detection

1. Find out any noise. The Gaussian filter is used for this purpose.
2.
3. Find the intensity gradient of image. A procedure analogous to Sobel is followed.
   i. Apply pair of convolution masks in x and y directions.
   ii. Find gradient strength and direction with:

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

$$\theta = \arctan\left(\frac{G_y}{G_x}\right)$$

   The direction is rounded to one of four possible angles (namely 0, 45, 90 or 135).
4. Non maximum suppression is applied. .This removes pixels that are not considered to be part of edge. Hence only candidate edges will remain.
5. *Hysterisis:* Canny uses two thresholds.
   i. If a pixel gradient is higher than the upper threshold, the pixel is accepted as an edge.
   ii. If a pixel gradient value is below the *lower* threshold, then it is rejected.
   iii. If the pixel gradient is between the two thresholds, then it will be accepted only if it is connected to a pixel that is above the upper threshold.

Canny recommended a *upper*:*lower* ratio between 2:1 and 3:1.

3. EXPERIMENT SETUP AND RESULTS

3.1 Experiment Setup

The prototype application is built on Android OS platform supporting version 5.0(Lollipop) and later with some extra permissions. The smartphone used was having camera of 13 MP. The operator will then operate on patients eyes using android smartphone.

Distance and angle of smartphone camera:
The camera should be held as near to eye as possible to obtain clear image of pupil and better results.

Flashlight and light intensity:
We found that flashlight created problems in eyes as patients experienced pain after use of flashlight. Manual overriding of flashlight is not available in current smartphones. So we tried to use method that won't involve necessity of flashlight in operation. Also the image can be taken in daylight without any reflection problem.

To check and note accuracy following steps are being observed.

1. Patient stands directly in front of camera and operator will capture image of eyes using smartphone.
2. The image is then cropped and converted into grayscale format.
3. The image is then processed using algorithm for cataract detection.
4. If cataract is found GPS is activated and nearby doctors are suggested using Google maps.

3.2 Results

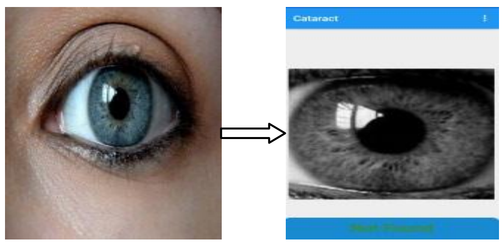


Fig -2. Non cataract test image

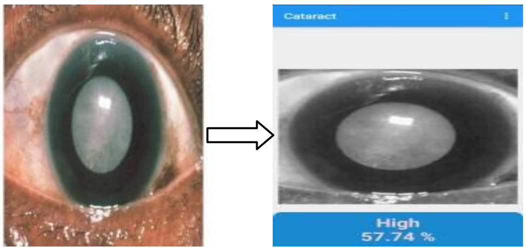


Fig -3. Cataract test image

Results were obtained based on 80-100 google test images and 25-30 live human images. It was found that google images produced accuracy of 85%-90% whereas it was reduced to 75%-80% on live human testing.

It was also noticed that image quality and resolution was and important factor for achieving accuracy in results.

3. CONCLUSIONS

This paper presents a cost effective and portable method of cataract diagnosis that can be used in smartphones. It enables any person having no technical knowledge to perform catract detection. This mobile application is portable and can be carried to areas with limited or no medical facilities and resources. It uses widely used simple grayscale format of image for processing and detection of cataract. This application is very effective since it produced 80% accuracy against 100 test images with negligible cost. Further study can be extended to increase accuracy and compatibilty of application with automated advanced diagnosis of cataract.

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