Development of Scale Invariant lens Opacity Estimation System using Hough Circle Detection Transform, Normalization and Entropy

Amol Jagadale, Santosh Sonavane, Dattatray Jadhav

Abstract**:** ***Clear eye lens is responsible for correct vision. Ageing effect acquires opacity at lens structure causing foggy or blurred vision. It is termed as cataract. This may become cause of permanent blindness if remain unidentified and untreated. Due to hazards change in environment and adoption of sluggish lifestyle many diseases like cataract are becoming universal challenge for health organization over the world. Lack of medication and diagnosis facility in developing countries makes cataract as savior vision problem. Proposed methodology suggests image processing based, low cost solution for lens opacity or cataract detection. In this system eye lens image from input image is acquired using Iterative Hough circle detection transform. It is normalized using Daugman's rubber sheet normalization algorithm which makes system scale invariant. Structural variation in normalized lens image is estimated in terms of entropy or mean value. Comparison of right and left half entropies of normalized image is basis for estimation of lens opacity. It is used to detect and categorize lens opacity or cataract. This system easily categorize lens opacity based on structural features of opacity in one of three grades such as "No cataract", "Cortical cataract" or "Nuclear cataract".***

Keywords**:** ***Cataract, Hough circle detection transform, Daugman normalization, Entropy, structural features***

I. INTRODUCTION

Opacity acquired inside lens is obstructing light passing to the retina and causes partial or complete blindness. The opacity inside eye lens is termed as cataract by ophthalmologist and medical science. Most predicated cause of developing eye lens cataract are smoking, use of steroids and eye injury. Even ageing of eye lens is most dominant, but it also getting observed in all age groups [1]. Hence it is serious and challenging for all developing nations. Image processing medical diagnosis is one of emerging field in medication. As it provides most cost effective and affordable diagnosis method, it is becoming most popular over the world. Proposed algorithm provides opacity detection and classification method using slit images. Small size, patient movement, eye rotation and variation in lens dimensions from patient to patient is challenge in image processing. Circular nature of eye lens can be easily characterized and localized using Hough circle detection transform. Research work presented uses lens normalization method to make overall system scale invariant. System can predict type of cataract based on the structural variation in lens structure.

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II. METHODOLOGY

Major development in technologies in image processing, neural network, pattern recognition, estimation and detection are making technology within reach of common man [2,3]. Lens images acquired using digital camera mounted on eyepiece of slit-lamp are major information source for the research. In proposed system the methodology as shown in Fig. 1 works in three steps such as lens localization, lens normalization and cataract detection as explained in Fig. 1. Structural features inside the lens structure are used as basis for estimating category of lens opacity or cataract [4].

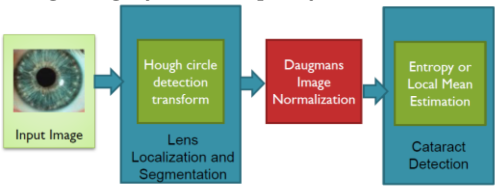

Fig. 1.Block diagram of lens opacity estimation system

A. Lens localization and extraction using Hough circle detection transform

Lens image is captured using digital camera. Here eyepiece mounted slit-lamp is most suitable. Eye lens circular in shape. It is challenging to detect as its radius varies. Variation occurs due to pupil dilation. In this experimental set up Hough circle detection transform is proposed for lens localization [5,6]. The steps used in this process are as below

- Read input RGB color image
- Crop and resize input image to 120 x 120 pixels size
- Convert resized image to grayscale image
- Apply Hough circle detection transform and get lens center and radius
- Generate mask and extract lens structure from grayscale image and convert it to binary image

P(x,y) is input color image from digital camera. It is in 24 bit representation per pixel. It is converted to gray scale image.

$$g(x,y) = 0.298P_r(x,y) + 0.587P_g(x,y) + 0.11P_b(x,y) \quad (1)$$

Where g(x,y) is gray scale image. Pr(x,y), Pg(x,y) and Pb(x,y)are red, green, and blue color planes.

Input image manually cropped and resized to 120 x 120 pixels to form z(x,y). This adjusts lens radius between 60 to 65 pixels. It is assumed that z(x,y) contains complete lens.

Hough circle detecton transform is applied on z(x,y). This detects radius and lens center. It converts input image into accumulator matrix of (a,b,r) triplet. Here (a,b) indicates circle center. And 'r' represents radius of circle passing though each pixel. The pixel having highest number of circles passing though it is lens center.

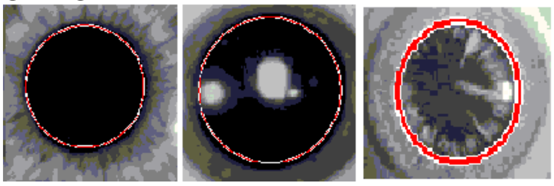

Fig. 2.Localized lens using Hough Circle detection transform

Fig. 2 displays the lens localized by Hough circle detection transform. Lens dimension are function of pupil dilation. To reduce computational overheads the lens is not segmented before normalization.

B. Lens normalization using Daugman's rubber sheet normalization

The input image is containing lens circle. Lens center and radius is input to Daugman's Normalization algorithm. This converts lens region to normalized square image. The output image dimension is fix 750 X 180 pixels. The transformation makes overall system scale invariant.

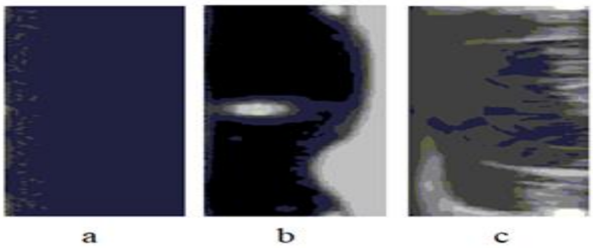

Fig. 3.Normalized lens images

Fig. 3 displays normalized lens for lens without cataract, nuclear cataract and cortical cataract.

C. Lens opacity detection and cataract classification

Lens opacity is categorized based on comparison of entropy of structural features. Opacity at center is named as "nuclear cataract". Lens opacity at out edge is termed as "cortical cataract". If it is observed at back side of lens capsule it is named as "posterior cataract" [7,8]. Normalized image reflects nuclear cataract on left half. It reflects cortical cataract on right side. It is not possible to detect posterior cataract using this method. The lens without cataract is clear. Hence entropy value of normalized image is less. If entropy of left half is greater than that of right half "nuclear cataract" is detected. If entropy of right half is large "Cortical cataract" is detected [6]. If mean or entropy is less than 10% "no cataract" is detected. Results of different normalized cataract is represented in Fig. 3.

III. IMPLEMENTATION OF PROPOSED METHOD

The flow chart for proposed system is as displayed in Fig. 4

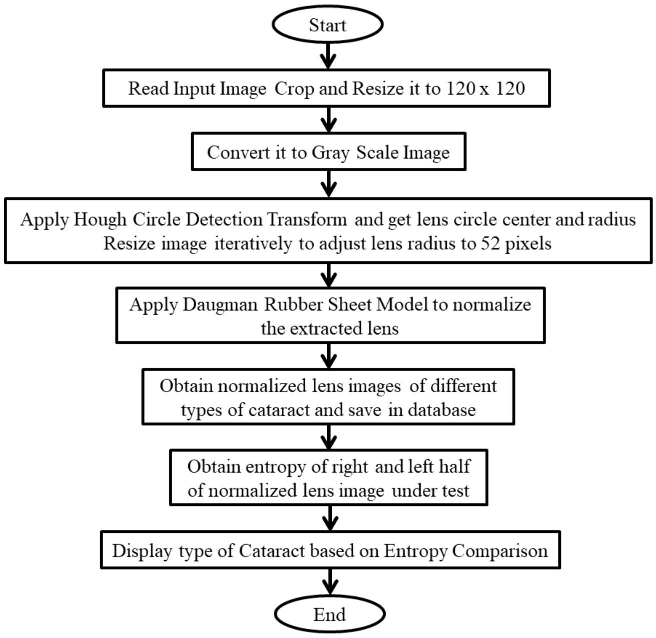

Fig. 4.Flow chart for cataract detection

Input image acquired is manually cropped. It is resized to 120×120 pixels. Hough circle detection algorithm returns lens center and radius values. Daugman Rubber Sheet Normalization uses these values. The result is normalized rectangular image representing lens.

Entropy or mean values are calculated for left and right half. Based on entropy values Cataract is classified [10]. The above flow chart is implemented in MATLAB and tested for set of images.

IV. RESULTS AND DISCUSSION

The dataset of 400 volunteers with and without cataract are acquired using slit lamp mounted digital camera. Results based on physical observation and results obtained from developed system are recorded. Confusion matrix is created to estimate the Sensitivity, Specificity and Accuracy of system [10,11]. It is represented in Table- I.

$$\text{Sensitivity} = \frac{TP}{(TP + FN)} \quad (2)$$

$$\text{Specificity} = \frac{TN}{(TN + FP)} \quad (3)$$

$$\text{Accuracy} = \frac{(TP + TN)}{(TP + TN + FP + FN)} \quad (4)$$

Here TP - "True Positive" termed as cataract is correctly classified

TN - "True Negative" termed as the Non cataract is correctly classified

FP - "False Positive" indicates Non cataract is incorrectly classified as having cataract

FN - "False Negative" reflects cataract is incorrectly classified as no cataract

Table- I: Confusion Matrix created for set of input images

	Predicted Cataract by proposed algorithm		
Actual observation		Yes	No
	Yes	242	13
	No	14	131

Proposed cataract detection system shows 93.25% accuracy. Here sensitivity and specificity of system are 94.90% and 90.34% respectively. System uses Active shape model based lens localization and preprocessing to extract lens from eye image adjusting lens center and image center to same location.

V. CONCLUSION

Lens radius in acquired image during slit lamp observation is function of pupil dilation. Hence making system scale invariant was challenging. The use of Hough circle detection transform with Daugman's rubber sheet normalization makes overall developed system scale invariant. Cataract type is function of opacity structural variation inside lens structure [12]. Cataract estimation based on comparison of right and left half of entropy or means of normalized image makes more accurate to categorize it in "No cataract", "Nuclear cataract or cortical cataract". The accuracy achieved by this method is 93.7%. The method is computationally efficient can be implemented on portable hardware platform.

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