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Active Shape Model based Correlative Assessment of Statistical Parameters to Detect Cataract

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***Abstract**: The lens opacity acquired due to clouding of eye lens causing blindness is called a cataract, its detection is challenge. Based on positional occurrence of opacity in a lens it is categorized as nuclear sclerotic, posterior sub-capsular, and cortical cataract. Excessive use of steroids medicines, smoking, ageing, or eye injury lens cause cataract. Gradual and progressive growth of opacity is occurring in lens due to agglomeration of water and protein molecules. The maximum reflected rays form object, that focusing at retina lead to clear understanding of object image. Opacity inside lens causes refraction, reflection and diffraction of reflected light from object. This affects interpretation of image due to poor retinal reception. The patient may be advised treatment or change in lifestyle to prohibit the further growth of cataract or to improve vision. Researches are suggesting methods for detection of cataract from lens images by analysis of color, structural, and optical parameters. The research work presented uses wide slit illumination lens images for analysis to detect cataract. Due to elliptical shape of lens proposed system prefers active shape model with region properties to segment lens structure. Mean pixel value and uniformity are parameters used to distinguish lens without cataract from lens with cataract. The statistical parameters are dependent on probability of pixel values. Hence, using these parameters, system can be made invariant to source illumination. Correlation is performed between parameter vector of input image, and that of known images from database to identify and classify cataract type.*

***Keywords**: cataract, lens image, Active shape model, statistical parameters, correlation.*

I. INTRODUCTION

Lens opacity or cataract causes partial blindness at early stage. It may become severe blindness in its mature stages. Cataract due to ageing of natural eye lens after age of 40 is more common. Based on its physical appearance in a lens structure it is categorized as nuclear sclerotic cataract start building opacity at lens center while cortical cataract grow at lens outer edge. It is fetching attention of researchers and world health organization as it is observed in minor edge children and it may lead to loss of eye vision though out of life.

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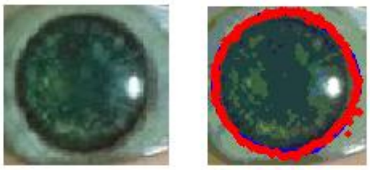
In developing countries where number of ophthalmologists are less compared to human population the cataract detection and treatment is challenge.

As well people are less aware of this disease. Eye lens surgery is only remedy which is for replacing the original lens with synthetic lens.

Ophthalmologist are using the slit lamp for diagnosis of cataract. In present research work the cataract images can be acquired using the slit lamp mounted digital imager and processed using modified image processing algorithms.

The color based segmentation, segmentation based on intensity spread or segmentation based on shape are most popular in computer-aided automated cataract detection process.



a b

Fig. 1. (a) Lens image with cataract, (b) ASM based lens localization using 25 land mark points

Lens in acquired image is elliptical, hence accuracy of a lens localization algorithm rules success of cataract detection methodology. The proposed method localize and segments eye lens using active shape model. The approximate lens circle is extracted and statistical parameters based correlation is used detect the severity of cataract.

II. RELAVENT RESEARCH REGARGING CATARACT

To automate cataract detection system researches are investigating fast and accurate algorithms for lens localization and pattern recognition. The correctness and success of computer added cataract detection method is based on accuracy of lens segmentation, feature extraction, and grade prediction. The cataract can be detected at earlier stages by analysis of a variation of pixels intensity patterns in lens image structure. [1-4]. 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 method for Posterior Sub-Capsular (PSC) and cortical cataract, and have suggested low level vision features in retro illuminated images for characterization of geometric structures and photometric appearances. Group sparsity-based constraint for linear regression is used by X. Gao et. al, [7] et. al to perform parameter selection, feature selection, and training of regression model for detection and categorization. Specular reflection, texture uniformity and average intensity variation are used by R. Supriyanti et.al, [8,9] for detection of cataract. W. Huang et.al, [10] has suggested learned ranking function for grading of nuclear cataract in a slit-lamp image with use of neighboring labeled images in a ranked image list. Ranking function is learned by direct optimization of ranking evaluation measure.

III. METHODOLOGY

Active shape model based image processing algorithm is developed for lens localization and statistical parameters of localized lens are extracted and correlated with that of images in database image to detect cataract. The eye lens images are acquired using the slit lamp mounted camera and processed. Due to variable and elliptical shape of lens from literature review it is observed that the success of detection of any image processing method depends on the correct and fast localization method of lens structure. The lens structure is elliptical or approximately circular, and its color and texture reflects severity of cataract. The lens without cataract is appears black, and has mean intensity threshold below 147 for Grayscale images with eight bit resolution.

Color based segmentations are also used, but error prone in case of immature, and cataract at early stage. Hence, the detection is less accurate in early stage cataract using color based segmentation. Due to a nearly circular shape of lens researches use hough circle detection transform based lens localization segmentation.

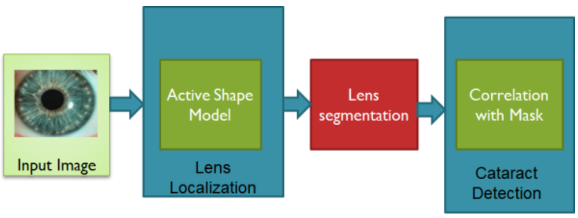


Fig. 2. Process of lens localization and feature extraction

In the proposed method the Active shape model based lens detection is used to extract the lens from eye structure. The input image is varied in dimension and shape of lens is exact circle. Lens edge is blur and is function of illumination source. The circle detection transform takes more time for unknown radius. As well, it returns many circles instead of single circle in case of blur image. The research review is also guiding to use method to detect irregular shape object such as active shape model. The method is computationally hungry and based on edge gradients. Prior training of model is required. It returns approximate shape of detected object. Here our object is lens which is nearly circular but, highly influenced by iris structure form outer side and cataract parameter from inner size. Hence, Active shape model based detection is most suitable. Information related to length of major and minor axis is extracted. The cross section of major and minor axis is considered as lens center and approximate lens is extracted. The statistical parameters of extracted lens are correlated with parameters of known images and type of cataract is detected.

A. Input Image Pre processing

Using slit lamp mounted digital camera, color image I(x,y) is acquired in RGB format and 24 bit resolution.

$$gi(x,y) = 0.298I_r(x,y) + 0.5871I_g(x,y) + 0.11I_b(x,y) \quad (1)$$

The gi(x,y) is gray scale image obtained by weighed combination of $I_g(x,y)$, $I_r(x,y)$ and $I_b(x,y)$, which are green, red and blue color planes.

Further, image gi(x,y), the gray scale image is cropped and resized to 120 x 120 pixels, such that the cropped image z(x,y) contain lens and part of iris.

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

Lens localization using ASM algorithm

To compensate variation in lens radius due to physical and technical parameters the parametric deformable model is most suitable. The Active shape model combines iterative refinement procedure with point distribution model [1]. For defining lens shape contour 25 landmark points are selected. The model is trained with training data set of 10 sample images with manually labeling of landmark points on lens contour. By transformation, training data is aligned into a common coordinates, such that it minimize sum of squared distances between landmark points labeled on different shapes. To optimize vector space, principle component analyses is performed on training shape.

Equation 3 represents approximate shape.

$$x = \bar{x} + \phi b \quad (3)$$

Here $\bar{x}$ indicates mean shape, b represents vector of shape parameters, and ϕ as set of Eigen vectors.

Initialization of shape, matching point detection, pose parameter update, model update shape and convergence evaluation are five steps flowed in Active shape model. The shape space and the image space transformation is described in equation 4.

$$X = T(x) = \begin{pmatrix} s\cos\theta & -s\sin\theta \\ s\sin\theta & s\cos\theta \end{pmatrix}\begin{pmatrix} x_i \\ y_i \end{pmatrix} + \begin{pmatrix} t_x \\ t_y \end{pmatrix} \quad (4)$$

The x denote shape in shape space while X denotes shape in image shape. The x_i and y_i denote position of i^{th} landmark point of shape model in shape space. Here model center in image space is represented by t_x and t_y. The Process starts with initialization, which searches match points around a current position. The initialization process selects appropriate pose parameter vector and shape vector. This is followed by moving each landmark point in model space, to find best match of landmark point in image space. The model searches matching points along the profiles normal to the model boundary considering current position of each model point. Edge of eye lens is find by taking derivative of intensity derivative on normal profile is utilized.

Iterative operations are performed to minimize the distance between estimated match point and model landmark points to minimize the error between previous and next iteration model.

Fig. 3. (a) original eye image, (b) lens localization and (c) extracted lens

The model return the mask with lens contour. Length of major axis and minor axis is obtained using region properties. The centroid of lens region is considered as center and half of shorter of major and major axis is considered as radius. Approximate lens circle is extracted for further processing.

The image displays the original image, lens detected, extracted lens. As, the model is deformable, the effect of variation in lens radius due to camera focusing is eliminated.

B. 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.

$$\text{Mean} = \sum_{i,j} x(i,j)p(i,j) \qquad (5)$$

$$\text{Homogeneity} = \sum_{i,j} \frac{p(i,j)}{1+|i-j|} \qquad (6)$$

$$\text{Smoothness} = 1 - \frac{1}{1+\sum_{i,j} x(i,j)} \qquad (7)$$

The variation in pixel values is considered as two dimensional random variable. The mean homogeneity and smoothness are calculated and compared with these parameters of lens without cataract. The parameters depending on probability of occurrence of pixel and not on positional values hence it makes the system invariant to scale and rotation.

IV. RESULT AND DISCUSSION

The eye images of 400 volunteers with and without cataract are obtained. Statistical features are calculated and compared. The results are communicated to ophthalmologist and verified from them. Proposed systems output and ophthalmologist are compared. Part of processed images results are displayed in Table I. It is observed that the results obtained from proposed cataract detection system are competent.

Table I 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 I Results of sample images with and without cataract.

Table II Confusion matrix from output table

Table Head		**Predicted Cataract by proposed algorithm**	
		Yes	***No***
Actual Observation	***Yes***	332	18
	No	15	35

Table II Categorization of 400 sample images cataract.

Table III Estimated Sensitivity, Specificity, and accuracy of proposed system Comparison of system results with results of ophthalmologists

Total Number of Images	**Cataract Affected**	**Sensitivity**	**Specificity**	**Accuracy**
400	350	0.904	0.7	0.9175

Table III Calculated parameters for 400 sample images of with and without cataract.

Table II and indicates confusion matrix. The accuracy indicated by above method is 91.75 % for set of 400 images Table III. The algorithm for detection of cataract has been implemented using MATLAB. Sample eye images are captured using slit lamp from volunteers at government hospital, Pandharpur.

V. CONCLUSION

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 active shape model used is accurate compared to Hough circle detection, and threshold based methods to detect the lens structure. As, ASM is deformable it makes lens detection independent on variation lens radius and scaling. The statistical parameters like mean, homogeneity and smoothness are used to differentiate lens with cataract and without cataract makes system scale and intensity invariant. The cataract detection accuracy is 91.75%.

Due to iterative operation in ASM, the overall cataract detection process is slow compared to other methods. Further, results can be improved by approximating lens localization and lens normalization.

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