Characterizing Eye Lens Images Using Active Shape Model, Normalization, And Support Vector Machine To Detect Cataract

A. B. Jagadale, S. S. Sonavane, D. V. Jadhav

Abstract: Extracting features of eye lens will be beneficial in identifying eye disease, and their categorization acquired due to opacity. The characterization lens is critical as, its localization is challenging. Smaller size, source reflections, and color variation due to opacity are hurdles in lens localization. Also, lens size varies due to iris deformation, focusing of camera, and change in image resolution. In the research work published here, image processing challenge of lens localization is addressed by using deformable active shape model (ASM). The circular lens is extracted using region properties like centroid of image. Extracted lens circle is normalized by Daugman rubber sheet normalization transform. The normalization process transforms lens circle with any radius to fix size rectangular image. Coefficient matrix is obtained by processing normalized image by discrete wavelet transform (DWT). The obtained coefficient are used as basis for categorization with support vector machine (SVM) based regression. Proposed system in this research work is suggested for detecting and categorizing lens opacity or cataract, tested for set of lens images, and achieved 95.25% cataract detection accuracy. Use of normalization process makes system independent of scale and rotation of image.

Index Terms: Cataract, Active shape model, Daugman rubber sheet model, discrete wavelet transform, support vector machine

1. INTRODUCTION

NATURAL eye lens without cataract is clear and transparent, and its image is black. The lens with cataract shows pixel intensity values higher than 147, and appears gray or white. Lens with cataract is non-transparent in appearance. The structure of nontransparent white portion decides the type of cataract. Loss of eyesight is common in developing countries like due to lack of awareness toward eye diseases, and regular checkups. The large number of patients compared to less no eye hospitals and ophthalmologist is also severe problem in emerging countries. Eye disease like cataract fetches attention of research due to its appearance in old age persons, diabetic patients, and children.

Automated cataract detection processes may release the huge burden over ophthalmologists, and help in documentation of patient history. Due to small size, and source reflection lens image acquisition, localization is challenging. Some sample images are displayed in figure 1. Literature review guides that the researches are using attributes like shape, color, intensity variation to localize lens. Threshold, and color based segmentation are less accurate. The variation in lens size in input images make researchers to investigate model based or transform based approaches of lens localization. Active shape model and Hough circle detection algorithm is most popular.

2 RELEVANT RESEARCH REGARDING CATARACT

Fast, accurate, scale and rotation invariant lens localization system is building block of automated cataract detection systems. Active shape mode is most suitable in this environment. Earlier stages cataract can be analyzed by study of the variation of pixels intensity patterns in lens image structure. [1-4]. Active shape model is suitable for irregular shape objects such as eye shape [5-6]. Model based approach is suggested by the J.Nayak for lens localization while he has suggested the support vector based categorization [7]. Y. Xu et. al, [8] 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, [9] 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. Specular reflection, texture uniformity and average intensity variation are used by R. Supriyanti et.al, [10,11] for detection of cataract. W. Huang et.al, [12] 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. From direct optimization of newly proposed approximation to a ranking evaluation measure, ranking function is learned.

3 METHODOLOGY

Research work presented in this paper focuses on development of computer-aided automated process to detect eye lens opacity from slit-lamp digital images. The process works with following steps, as preprocessing, lens localization,
lens extraction, lens normalization, feature extraction, model training with features, and feature based detection, and categorization of cataract. Overall operational process is as displayed in figure 2.

![Fig. 2. ASM, SVM cataract detection process.](image)

Eye image includes eyelids, sclera, iris and lens at center. The lens size is different for every patient. It varies due to dilation, and iris contraction. The resolution and focusing of imaging system also gives variation in the radius of lens. Most researches working on iris, and lens segmentation, taken preprocessed images from database having fixed iris radius. To avoid complication in detection of multiple circle of a iris and lens, input image is cropped to eliminate major part of iris, and including complete lens circle. This process will minimize computational overheads of detection of iris.

Let (x,y) is acquired color eye image using slit lamp in RGB format with 24 bit resolution per pixel, further the input image converted to gray scale image g(i, j).

The input gray scale image is cropped and resized to 120x120 pixels. It is assumed that the cropped image z(x,y) contain lens, and part of complete iris.

Such that

\[ z(x, y) \in g(x, y) \]  

In this research work deformable Active shape model is used for lens localization. To avoid inclusion of additional contours of iris in lens circle, using region properties approximate lens circle is extracted. The extracted lens circles from images from database are having different radius. The Daugman rubber sheet normalization process will convert spatial domain lens image into fix rectangle of parameters. This will make system scale invariant. The extraction of discrete cosine transform coefficient transform image to parametric matrix.

Support vector machine is trained with vector of known images and used to detect appropriate class of input image. Active shape model is parametric deformable model that combines point distribution model (PDM) with iterative refinement procedure, which gives extract the lens contour [1]. Model is consistent with training data set, and shape of lens is described by the position of 25 landmark points, labeled manually during training. Training data is organized into a consistent with training data set, and shape of lens is described by the position of 25 landmark points, labeled manually during training. Training data is organized into a common coordinates, such that it minimizes sum of squared distances between the landmark points on different shapes. Principal component analysis is performed on aligned training shapes of object in images form database. The shape is approximated as mentioned in equation given below.

\[ x = \bar{x} + \phi b \]  

where \( \bar{x} \) : mean shape

The transformation includes initialization, matching point detection, pose parameter update, model update shape and convergence evaluation. Conversion between shape space and the image space is described by equation 3. Shape model in the shape space, and in image space is denoted as \( x \) and \( X \), where \( x_i \) and \( y_i \) denote position of \( i^{th} \) landmark point of shape model in shape space and \( t_x \) and \( t_y \) represents model center in image space. Initialization searches match points around a current position of model in lens image, which selects proper pose parameter vector and shape vector. For each landmark point on the model in image space, the nearby best matching point is searched along boundary of lens, where the landmark point will be moved. Matching points are searched along the profiles normal to the model boundary

\[
X = T(x) = \begin{pmatrix} \sin \theta & -\cos \theta & x_i \\cos \theta & \sin \theta & y_i \\end{pmatrix} + \begin{pmatrix} t_x \\ t_y \end{pmatrix}
\]

through each model point. Derivative of intensity values on normal profile is utilized to find edge of lens. Iterative operations minimizes the distance between estimated match point and model landmark points to minimize the error between previous and next iteration model. The model return the mask with lens contour as displayed in figure 3. Using region properties, length of major axis, minor axis are obtained. To avoid errors at edge approximate lens circle is extracted using axis cross section as center, and half of minor axis as radius. Output images in figure 4 displays the original image, lens detected, extracted lens. Deformable nature of model eliminates effect of variation in lens radius due to camera focusing and pupil dilation. Further the lens circle is normalized using Daugmans rubber sheet normalization, which transforms lens circle in spatial domain in to rectangular parametric domain of fix size. Here \( r \) is the radius lens circle, while \( (x_1(\theta), y_1(\theta)) \) and \( (x_2(\theta), y_2(\theta)) \) are the coordinates of the pupillary boundaries in the direction \( \theta \) and \( r \). As outcome it gives normalized rectangular image \( I(r, \theta) \rightarrow I(x,y) \) resized to 750x350 pixels for computational simplicity.

![Fig. 3. Lens localization using ASM (A) without cataract, (b) Nuclear cataract, and (c) Cortical cataract.](image)

![Fig. 4. (a) Original eye image, (b) Lens localization and (c) Extracted lens](image)
I(x(r, θ), y(r, θ)) → I(r, θ)......(4)

x(r, θ) = (1-r)x_p1(θ) + rx_p2(θ) ......(5)

y(r, θ) = (1-r)y_p1(θ) + ry_p2(θ) ......(6)

Figure 5 displays normalized images of extracted lens circles.

The two dimensional wavelet transform performs decomposition of input matrix into detail coefficients, horizontal vertical and diagonal coefficient matrix (LL, LH, HL, HH). The detail coefficient matrix (LL) is used as feature coefficient matrix as it contains highest information content.

Two dimensional discrete wavelet transform is represented by

\[ f(t) = \sum_k \sum_j a_{jk} \psi_{jk}(t) \] ......(7)

The statistical parameter calculated for images in database for classes, as no cataract, nuclear cataract and mature cataract is multidimensional vector space. The classification using traditional neural network is having data over fitting and generalization problem. Thence multidimensional support vector machine is preferred for classification and regression. The system returns class of image as category of cataract.

4 RESULTS AND DISCUSSION

Proposed algorithm is implemented using MATLAB software. The overall cataract detection system is trained for classes such as no cataract, nuclear cataract, and mature cataract. System is tested with set of 400 images obtained from volunteers with and without cataract. The results obtained from automated system are compared with diagnosis of ophthalmologists. The confusion matrix is formed from observation table for calculating overall detection accuracy. Results are as listed in Table 1.

| Table 2 shows confusion matrix generated to calculate sensitivity, specificity and accuracy obtained. |

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<td><strong>COMPARISON OF SYSTEM RESULTS WITH RESULTS OF OPHTHALMOLOGISTS</strong></td>
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Algorithm developed shows sensitivity of 97.59%, while accuracy is 95.25%.

5 CONCLUSION

The point distribution and deformable Active shape model is most suitable for lens localization. The deformable nature of ASM model makes lens localization invariant to lens radius. Extracted lens circle is using region properties normalized using Daugman rubber sheet normalization makes detection system invariant to scale, and rotation. DWT based extracted features with SVM based regression enhances the accuracy to 95.25%. The automated system is useful for computer aided detection and categorization of cataract and reduce error in manual gradation of cataract.

REFERENCES


