Detection of Degree of Sickness of Affected Eye Using Fuzzy Logic and Histogram Analysis

Manisha Barman, J. Paul Choudhury and S. Biswas

Abstract Cataract is a clouding of the lens inside the eye which leads to a decrease in the vision. It is the most common cause of blindness and is conventionally treated with surgery. The main objective of this paper is to develop a system which helps to detect cataract in affected eyes. The system consists of selection of area of interest from an image of an image and extraction of certain features of images. The proposed work consists of selection of the area of interest from an eye image and formation of membership values and their mean values from the textual properties of the image with an objective to differentiate between the normal and affected eye for the purpose of detection of degree of sickness of the eye. The said work is confirmed from the result as obtained from the irregular frequency distribution of the input image and the value of irregular deviation of the frequency of the image. A set of images consisting of normal and affected eyes has been collected for carrying out this work.

Keywords Cataract eye · Membership function · Irregular distribution · Mean value · Irregular deviation

1 Introduction

A cataract is a clouding of the lens inside the eye which leads to a decrease in vision. It is the most common cause of blindness and is conventionally treated with surgery. Age-related cataracts are responsible for 51 % of world blindness, about

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20 million people. Globally, cataracts cause moderate-to-severe disability in 53.8 million (2004), 52.2 million of whom are in low- and middle-income countries. In many countries, surgical services are inadequate, and cataracts remain the leading cause of blindness. Even where surgical services are available, low vision associated with cataracts may still be prevalent as a result of long waits for, and barriers to, surgery—such as cost, lack of information, and transportation problems. This problem is largely seen in the rural section of India so we decided to work on this kind of abnormality.

The colored part of the eye controls the amount of light that enters into the eye. It is the most visible part of the eye. It is called iris. The iris is divided into two zones: pupillary zone, the inner part of the iris that forms the pupil's boundary, and ciliary zone, the remaining part of the iris that extends into the ciliary body. The color of the iris is determined by a dark pigment called melanin.

Danciu et al. [1] have used a feature extraction approach inspired by the scale-invariant feature transform (SIFT) algorithm. They have used color gradient based on principal component analysis (PCA) to discover the correct key points position, own color corner detection algorithm, for getting result they used images of human eye iris affected by melanoma and also on images representing color textures of healthy iris.

Senthilkumaran and Rajesh [2] have used a survey based on the theory of edge detection for image segmentation using soft computing approaches such as fuzzy logic, genetic algorithm, and neural network.

Adeli and Neshat [3] have used a fuzzy expert system for the diagnosis of heart disease. The authors have used several variables, viz. as chest pain type, blood pressure, cholesterol, resting blood sugar, resting maximum heart rate, sex, electrocardiography (ECG), exercise, old peak (ST depression induced by exercise relative to rest), thallium scan, and age as inputs. The status of the patients as healthy or sick has been used as output. Four types of sickness have been used as output. These are Sick s1, Sick s2, Sick s3, and Sick s4.

Tobias and Seara [4] have used an approach to threshold the histogram according to the similarity between gray levels. Such a similarity is assessed through a fuzzy measure. In this way, they have overcome the local minima that affect most of the conventional methods. The experimental results have demonstrated the effectiveness of the proposed approach for both bimodal and multimodal histograms.

Ercal et al. [5] have proposed a simple and effective method to find the borders of tumors as an initial step toward the diagnosis of skin tumors from color images. The method has made use of an adaptive color metric from the red, green, and blue (RGB) planes that contain information to discriminate the tumor from the background. Using this suitable coordinate transformation, the image has been segmented. The tumor portion has been extracted from the segmented image, and borders have been drawn.

Xu et al. [6] have developed a three-step segmentation method using the properties of skin cancer images. The steps of this method are as follows: (1) preprocessing: A color image has been first converted into an intensity image in such a way that the intensity of a pixel can illustrate the color distance of that pixel with the color of the background. The color of the median of a set of pixels in small window of the images has been taken as the color of the background. (2) Initial segmentation: A threshold value has been determined from the average intensity of high-gradient pixels in the obtained intensity image. To find approximate lesion boundaries, this threshold value has been used. (3) Region refinement: Using edge information of the image, a region boundary has been refined. This has involved in initializing a closed elastic curve at the approximate boundary, and shrinking and expanding it to fit to the edges in its neighborhood.

A fuzzy rule base system has been designed for the detection of heart disease [7, 8]. The developed system has seven inputs. These are chest pain type, resting blood pressure in mm (Trestbps), serum cholesterol in mg (Chol), numbers of Years as a smoker (years), fasting of blood sugar (fbs), maximum heart rate achieved (thalach), and resting blood rate (trestbpd). The angiographic disease status of heart of patients has been recorded as output. It is to state that diagnosis of heart disease by angiographic disease status is assigned by a number between 0 and 1, and that number indicates whether the heart attack is mild or massive.

The work related to detect the sickness of eye (cataract) using image processing system cannot be done earlier. That is the reason to carry out the research work in this line. Here, it is proposed to take images of eyes from normal and sick persons. Thereafter, region of interest from the image of eye has to be taken. Membership functions under fuzzy logic have to be applied on the pixel value of image. After selecting the suitable membership function, column-wise mean value of membership has to be calculated. From the mean value of the degree of cataract can be detected. The said result has to be cross-checked by applying histogram analysis of the pixel values and making the irregular deviation of the frequency distribution value.

2 Methodology

In proposed system, two different approaches have been used. One is using membership function under fuzzy logic. The proposed system has produced membership values and calculated their mean value. On the other hand, histogram analysis has been used to find out their frequency distribution. The derived irregular distribution has used to distinguish between two sets of images.

The flow diagrams of two approaches are given in Figs. 1 and 2.

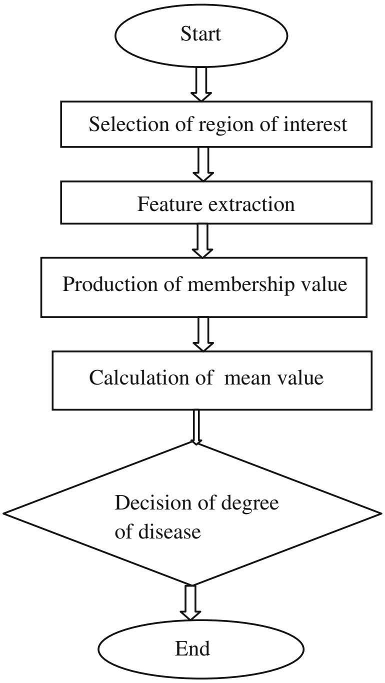


Fig. 1 Flow diagram of approach I

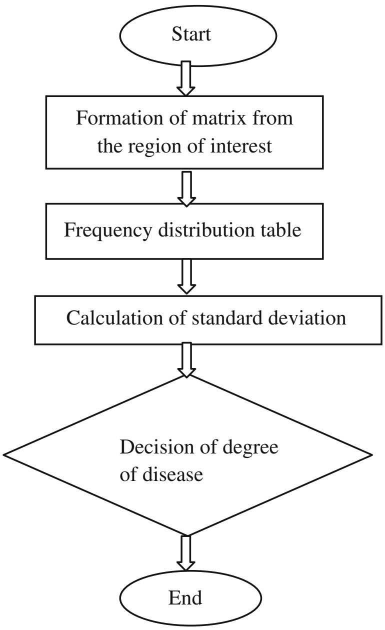


Fig. 2 Flow diagram of approach II

2.1 *Fuzzy Membership Function*

2.1.1 *Z*-shaped Base Membership Function

The *Z*-shaped base membership function is a spline-based function of μ_A of vector x and depends on two scalar parameters p and q that locate the extremes of the sloped portion of the curve. The *Z*-shaped base membership function μ_A of vector x has been represented by

$$\mu_A(x:\ p,q) = \left\{ \begin{array}{ll} 1 & \text{if } x \le p \\ 1-2\left(\frac{x-p}{q-p}\right)^2 & \text{if } p \le x \le p+q/2 \\ 2\left(\frac{x-q}{q-p}\right)^2 & \text{if } (\mathrm{p}+\mathrm{q})/2 \le x \le q \\ 0 & \text{if } x \le q \end{array} \right\}$$

2.1.2 Sigmoid-based Membership Function

The sigmoid function, $\mu_A(x, [p, r])$, as given in the following equation by $\mu_A(x, p, r)$, is a mapping on a vector x and depends on two parameters p and r. Depending on the sign of the parameter p, the sigmoidal membership function is inherently open to the right or to the left and thus is appropriate for representing concepts such as “very large” or “very negative.” More conventional-looking membership functions can be built by taking either the product or difference of two different sigmoidal membership functions

$$\mu_A(x:p,r) = \frac{1}{1+\mathrm{e}^{-p(x-r)}}$$

2.1.3 Gaussian Combination Membership Function

$$\mu_A(x;\ \sigma,c) = \mathrm{e}\frac{-(x-c)^2}{2\sigma^2}$$

The function gauss2mf is a combination of two parameters sig and c. The first function, specified by sig1 and $c1$, determines the shape of the leftmost curve. The second function specified by sig2 and $c2$ determines the shape of the rightmost curve. Whenever $c1 < c2$, the gauss2mf function reaches a maximum value of 1. Otherwise, the maximum value is less than one.

2.2 Irregular Distribution

From the histogram of image, irregular deviation has been calculated using following steps.

1. If h_i be the amplitude of histogram at index i, then the mean value M_H is given as follows:

$$M_H = \frac{1}{256}\sum_{i=0}^{255} h_i \tag{1}$$

2. Absolute of histogram derivations from this mean value H_{Di} is given as follows:

$$H_{\mathrm{Di}} = |h_i - M_H| \tag{2}$$

3. Irregular Deviation I_D is given as follows:

$$I_D = \sum_{i=0}^{255} H_{\mathrm{Di}} \tag{3}$$

From this irregular deviation whether the taken two samples are both of same kind or not have been calculated.

3 Implementation

Step 1: Conversion of RGB image to gray image
Eye images have been collected from the CASIA [9]. Snapshot of the selected sample input images in the original in RGB form has been converted into gray form. The corresponding pixel value has been used in step 2.

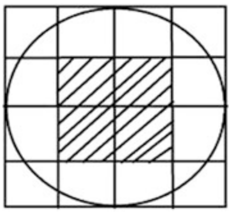


Fig. 3 Selection of region of interest

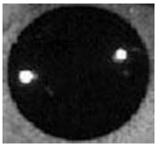


Fig. 4 Sample taken

Fig. 5 Region of interest

Step 2: Selection of Region of Interest
A lot of samples have been taken to find out some deformity in these samples.
From the selected image, the region of interest has been taken. Original sample has been broken into four coordinates, and further, each coordinate also has been broken into four coordinates; thereafter, region of interest has been taken as furnished in Fig. 3.
By using above process, the redundant part from the sample image has been eliminated (Figs. 4 and 5).

Step 3: Calculation of Fuzzy Membership value
Different membership functions (Zmf, Smf, gauss2mf, etc.) have been applied on the pixel values of the region of interest of selected image. It has been observed that *Z* membership function has produced best result on basis of minimum difference of the fuzzy original value of pixel value and the membership value as obtained.

Step 4: Calculation of Mean Value
The mean value of the membership value column wise has been calculated.

Step 5: Calculation of irregular deviation using histogram analysis generating frequency distribution table
Histogram analysis has been carried out on the region of interest of the image. From histogram analysis, frequency distribution table has been formed.

Step 6: Irregular deviation of the frequency has been calculated from the frequency distribution table.

Step 7: The instructions as narrated in step 1 to step 6 have been executed for two class images (normal eye and eye with cataract). From the mean as calculated in step 4 and the irregular deviation as calculated in step 6, the degree of sickness (cataract affected) of eye can be detected.

Step 8: The analysis as made from the value as obtained in step 4 can be confirmed from the analysis as made from the values as obtained in step 6.

4 Result

It has been observed that mean value of normal eye lies between 0.919 and 0.992 and that of affected eye lies between 0.525 and 0.766. The irregular deviation of normal eye lies between 1,031.5 and 1,192 and that of affected eye lies between 344 and 875.35. The computation of mean value for normal eye and cataract-affected eye has been furnished in Tables 1 and 2, respectively.

The computation of irregular deviation for normal eye and cataract-affected eye has been furnished in Tables 3 and 4, respectively.

Table 1 Mean value for normal eye

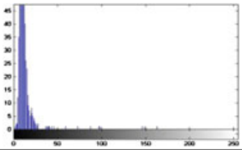
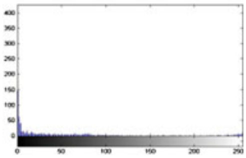
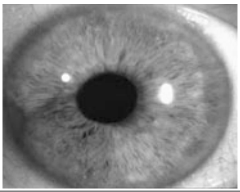
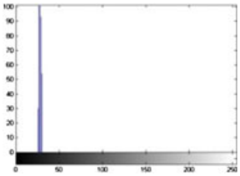
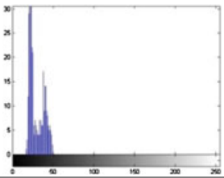
Sample	Histogram	Mean value
		0.9917
		0.9596
		0.9761
		0.9191

Table 2 Mean value for defective eye

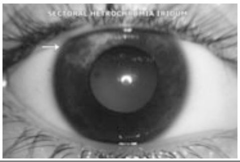
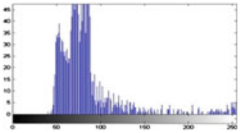
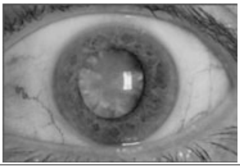
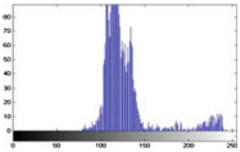
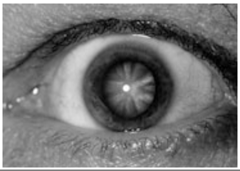
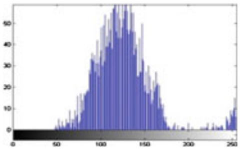
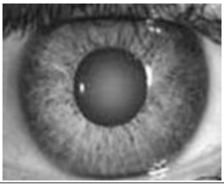
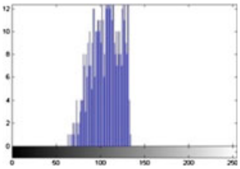
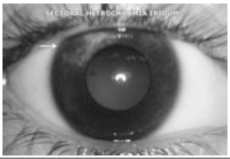
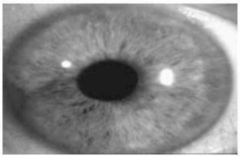
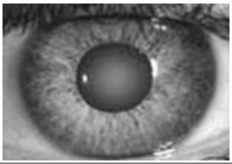
Sample	Histogram	Mean value
		0.7662
		0.5262
		0.5251
		0.6424

Table 3 Irregular deviation for two normal eyes

Sample 1	Sample 2	Irregular deviation
		1,192
		1,031.533

Table 4 Irregular deviation for a normal and a defective eye

Sample 1	Sample 2	Irregular deviation
		875.3514
		344

5 Conclusion

In this proposed technique, sample images are taken from normal and sick persons. The images may be distorted due to the heterogeneous communication media and for using different computer platforms. Therefore, it is necessary to rectify the image as good as possible so that the noise can be eliminated, the image will be of good quality, and the available pixel value will be nearest to its original value. That is the reason for using fuzzy logic.

After getting region of interest of images, it is necessary to remove noise from the images based on the pixel value. Applying proper fuzzy membership value, it is desirable that the minimum changes should make the selected region of interest more suitable to work. Three types of fuzzy membership functions have been applied for proper selection of membership functions.

Analyzing various images, it has been observed that if the mean value is 0.996 (approx), the condition of eye is all right; if it is 0.96 (approx), existing condition of eye is all right, but in course of time, it may lead to cataract. Similarly, if the mean value is 0.75 (approx), the eye has been attacked by cataract, but in a mild condition, where as if it is 0.64, the cataract condition is massive.

Similarly, the value of irregular deviation is 1,032, although the condition is all right at present, but in course of time, it may affect cataract. Similarly, if the value of irregular deviation is 874, the eye has been attacked by cataract, but the degree of sickness is mild. By using the proposed methodology, the analysis as obtained from one method (calculation of mean) can be cross-checked by the analysis as obtained from another method (calculation of irregular deviation). The condition of eye of new person can be detected by using this proposed methodology.

To take betterment of the result, some other soft computing models such as particle swarm optimization algorithm, ant colony optimization algorithm, tabu search method, and firefly algorithm can be attempted for more accurate performance.

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