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An Analytical Approach On Glaucoma Diagnosis Using Fuzzy Knowledge Based Expert Systems

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Abstract
This dissertation reports a new system for the segmentation of glaucoma diagnosis in the early stage using the exception handling techniques which enhance a rule-based fuzzy system and expert prediction analysis. In general we can very well create a fuzzy system to match any set of matching or non-matching input-output data's. Further we extended the same in to the fuzzy logic models, particularly fuzzy inference systems, which consist of number of conditional based rules. The designer/predictor who understand this system can describe or predict any systems. In fuzzy logic, the truth of any statement is based on their degrees unlike other standard conditional logical systems and predictors. The results against glaucoma diagnosis are promisingly, shows its superiority like a kind of expert prediction.

I Introduction

Medical image processing plays a vital role in the past two decades in the real life scenario. The theory of fuzzy logic, soft computing and artificial intelligence are the interesting and useful tools, which leads to the good theoretical and practical predictions to represent imprecision of the information [15].

One of the most important areas where the fuzzy expert set theory is very much applicable is, to process medical images and diagnosis for few diseases [10]. The term medical image is a superimposed concept for the relationship between symptoms and diseases [18]. There are varieties of models involving fuzzy soft computing techniques to deal with different complicated aspects of medical image diagnosis [9,11]. For example, fuzzy logic, a knowledge base expert system diagnosis Alzheimer disease, Anaesthesia (quantifying the medicine level for Anaesthesia), identification of cancer cells, glaucoma diagnosis and so on [14].

Glaucoma is a condition that causes damage to the human eyes, which is nothing but the optic nerve, gets worse over a period of time [1]. If the optic nerve gradually deteriorates, then blind spots develop the visual field .Basically glaucoma gives a kind of pressure inside the eye [16]. If the pressure level is increased after a certain level then it can damage the optic nerve which leads to vision loss some times its affects the human brain too [6]. If the age is 40 and above, family history related to glaucoma or retinal eye, BP, sugar level, diabetes, nerves issue and thyroid issues are considerably as variables. We considered these variables in order to get some precise results related to predict the glaucoma [7, 12].

Actually an intrinsic deterioration of the optic nerve, leads to high fluid intraocular pressure on the front part of the eye is often called as glaucoma disease [2]. This high fluid pressure, flows out of the eye through a mesh-like channel. When the channel gets blocked, the liquid builds up the front part of the eye [13]. Obviously the pressure is brought down the glaucoma disease. There is no common reason for this kind of high fluid pressure [3].

The following are the few medical tests in general the Ophthalmologists will perform, to identify the glaucoma [4,17]:

- Measuring intraocular pressure (Tonometry)
- Testing for optic nerve damage with a dilated eye examination and imaging tests
- Checking for areas of vision loss (visual field test)
- Measuring corneal thickness (Pachymetry) and
- Inspecting the drainage angle (Gonioscopy)

This dissertation is organized as follows. Section II recalls some basic terminologies and background of fuzzy knowledge based expert system and soft computing analysis. In section III, edge detection algorithm is arrived with the concept of convolutional operator and Z transform. Section IV deals the noise reduction using extended Kalman filtering algorithm to reduce the noises in the image. Section V implements the Fuzzy knowledge base expert system for glaucomatous eye and non-glaucomatous eye. Section VI concludes the dissertation.

II Background of fuzzy knowledge based expert system for glaucomatous eye and non-glaucomatous eye

There are varieties of models involving fuzzy knowledge based expert system to deal with different complicated aspects of medical diagnosis. The concept of Interval Valued Fuzzy Matrix(IVFM) is developed for dealing with the uncertainties present in most of our real life situations. The concepts of IVFM and the generalized concepts of fuzzy was extending the max, min operations of Fuzzy algebra $\mathrm{F} = [0,1]$. Many authors have extended Sanchez's approach for medical diagnosis using the representation of an interval valued fuzzy matrix, fuzzy soft set matrix and so on.

Our new proposed method named as exception handling techniques which enhances a rule-based fuzzy system and expert prediction analysis. The proposed system for glaucoma disease diagnosis uses the rule based linguistic approach of the objects belonging to the region of conversion from the eye sight based on knowledge based fuzzy rule. The region of convergence includes the following:

- Utmost Left (U_L)region
- Left (L)region
- Centre (C)region
- Right (R) region and
- Utmost Right (U_R)region

which includes the vertical and horizontal meridians which will be treated later as a change of order of the vertical stripe into the horizontal stripe and vice versa. This leads to give a ratio between the disc and excavation.

For that we used the following techniques:

- Edge detection based segmentation algorithm
- Fuzzy rules
- Contour detection
- Visual criteria of decimation
- Spatial conformity
- Enhancing compactness between the edges

The following are the three major methods to assess optic nerve (ON) retinal nerve fiber layer (RNFL).

Method I:

The ISNT rule [the thickest part of a healthy neural rim is located in the inferior quadrant, followed by the superior, nasal and temporal quadrants]

Method II:

In this method, the five areas which are evaluated as: optic disc size, rim tissue width using the ISNT rule, presence of RNFL loss, presence of peripapillary atrophy (PPA) and presence of disc haemorrhages.

Method III:

cup-to-disc ratio (CDR)

The above said methods are used by ophthalmologists. In this dissertation we analysed and predict the same with the help of soft computing techniques.

III Edge detection through convolutional operator

The edge detection algorithm is arrived with the concepts of convolutional operator and Z transform.

The convolutional operator involves the following steps:

Step 1:

Filtering the noises:

To overcome these issues several de-noising algorithms were developed and implemented like Kalman Filter, Weiner filter, Extended Kalman filter, Gaussian filter, median filter and so on.

Step 2:
Apply the gradient computation algorithm towards the variables namely Utmost Left (U_L), Left (L), Centre (C), Right (R), Utmost Right (U_R) and computed through the transfer function and Z transform are,

$$\| G_c \| = \sqrt{\left(\frac{\partial t}{\partial L}\right)^2 + \left(\frac{\partial t}{\partial R}\right)^2 + \left(\frac{\partial t}{\partial U_L} - \frac{\partial t}{\partial U_R}\right)^2} \qquad (1)$$

Now considerc_{ij} with m sources S_i(left side of an eye), $i = 1$ to m and ndestinationsD_j, $j = 1$ to n (right side of an eye). Let $a_i = F(UL_i, L_i, C_i, R_i, UR_i)$ be the Fuzzy Normal eye (FN) and$b_j = F(UL_j, L_j, C_j, R_j, UR_j)$ be the Fuzzy Suspected eye of having Glaucoma(FSG). Here FN and FSGare consideredfor the fuzzy membership functions. Then the problem is extended to determine the knowledge based approach under fuzzy environment to diagnose the glaucoma.

Step 3:
Fuzzy expert system is divided into the following 7 stages.

- In the 1st stage, difference between the existing normal eye (FN) and suspected eye of having glaucoma of utmost left corner are considered, i.e.$(FN \sim FSG) = F(UL_i \sim UL_j)$, for every$i = 1$ to m and $j = 1$ to n.
- In the 2nd stage, difference between the existing normal eye (FN) and suspected eye of having glaucoma of left corner are considered, i.e.$(FN \sim FSG) = F(L_i \sim L_j)$, for every$i = 1$ to m and $j = 1$ to n.
- In the 3rd stage, difference between the existing normal eye (FN) and suspected eye of having glaucoma of centre portion are considered, i.e.$(FN \sim FSG) = F(C_i \sim C_j)$, for every$i = 1$ to m and $j = 1$ to n.
- In the 4th stage, difference between the existing normal eye (FN) and suspected eye of having glaucoma of right corner are considered, i.e.$(FN \sim FSG) = F(R_i \sim R_j)$, for every$i = 1$ to m and $j = 1$to n.
- In the 5th stage, difference between the existing normal eye (FN) and suspected eye of having glaucoma of utmost right corner are considered, i.e. $(FN \sim FSG) = F(UR_i \sim UR_j)$, for every$i = 1$ to m and $j = 1$ to n.
- In the 6th stage, the difference between existing normal eye (FN) and suspected eye of having glaucoma (FSG) is swapped(like vertical portion of elliptical edge detection is swapped with horizontal) and noted the changes of reflexive, symmetric and transitive properties of elliptical edges.
- In the 7th stage, proceed the vice versa of the 6th stage.

Step 4:

The membership function of maximum and minimum difference between the existing normal eye (FN) and suspected eye of having glaucoma (FSG) of Utmost Left region is noted as,

$$\mu_{UL_{ij}}(\chi) = \sum_{i=1}^{m} \sum_{j=1}^{n} F(UL_i) - F(UL_j) \quad (2)$$

$$\Delta UL_{ij} = \sum_{i=1}^{m} \sum_{j=1}^{n} \mu_{UL_{ij}}(\chi) - c_{ij} \quad (3)$$

with $\mu_{UL_i} \cup \mu_{UL_j} = \max[\mu_{UL_i}(\chi), \mu_{UL_j}(\chi)]$ and $\mu_{UL_i} \cap \mu_{UL_j} = \min[\mu_{UL_i}(\chi), \mu_{UL_j}(\chi)]$.

Now construct the membership function of maximum and minimum difference between the existing normal eye (FN) and suspected eye of having glaucoma (FSG) of Left region is noted as,

$$\mu_{L_{ij}}(\chi) = \sum_{i=1}^{m} \sum_{j=1}^{n} F(L_i) - F(L_j) \quad (4)$$

$$\Delta L_{ij} = \sum_{i=1}^{m} \sum_{j=1}^{n} \mu_{L_{ij}}(\chi) - c_{ij} \quad (5)$$

with

$\mu_{L_i} \cup \mu_{L_j} = \max[\mu_{L_i}(\chi), \mu_{L_j}(\chi)]$ and

$$\mu_{L_i} \cap \mu_{L_j} = \min[\mu_{L_i}(\chi), \mu_{L_j}(\chi)]$$

Now construct the membership function of maximum and minimum difference between the existing normal eye (FN) and suspected eye of having glaucoma (FSG) of Centre region is noted as,

$$\mu_{C_{ij}}(\chi) = \sum_{i=1}^{m} \sum_{j=1}^{n} F(C_i) - F(C_j) \quad (6)$$

$$\Delta C_{ij} = \sum_{i=1}^{m} \sum_{j=1}^{n} \mu_{C_{ij}}(\chi) - c_{ij} \quad (7)$$

with

$\mu_{C_i} \cup \mu_{C_j} = \max[\mu_{C_i}(\chi), \mu_{C_j}(\chi)]$ and

$$\mu_{C_i} \cap \mu_{C_j} = \min[\mu_{C_i}(\chi), \mu_{C_j}(\chi)]$$

In a similar way proceed for Right and Utmost Right regions.

The architecture of the proposed system is as follows:

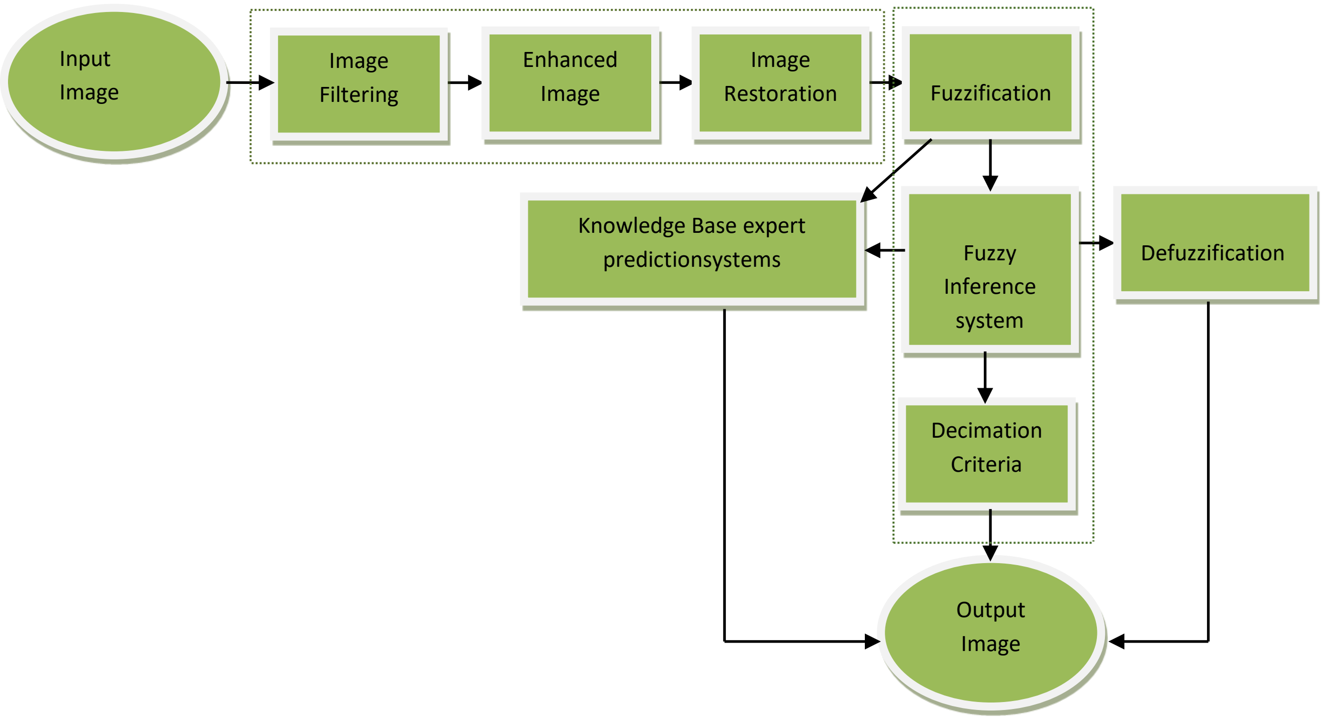


Figure 1: Block diagram for the proposed decision making algorithm based on fuzzy expert system

After arriving the values of $\mu_{R_i} \cup \mu_{R_j}$, $\mu_{R_i} \cap \mu_{R_j}$ and $\mu_{UR_i} \cup \mu_{UR_j}$, $\mu_{UR_i} \cap \mu_{UR_j}$ then, find the difference between $\mu_{UL_i} \cup \mu_{UL_j}$ and $\mu_{UR_i} \cap \mu_{UR_j}$. Similarly find the difference between $\mu_{L_i} \cup \mu_{L_j}$ and $\mu_{R_i} \cap \mu_{R_j}$, and compare these values as follows:

$$\Delta_{UL} = |\mu_{UL_i} - \mu_{UL_j}|$$
$$\Delta_{L} = |\mu_{L_i} - \mu_{L_j}|$$
$$\Delta_{C} = |\mu_{C_i} - \mu_{C_j}|$$
$$\Delta_{R} = |\mu_{R_i} - \mu_{R_j}|$$
$$\Delta_{UR} = |\mu_{UR_i} - \mu_{UR_j}|$$

It is then defuzzified for the sake of verification with respect to the crisp case.

IV Noise Reduction using Extended Kalman Filter

The Extended Kalman Filter techniques yields a good noise reduction in all the regions like Utmost Left (U_L), Left (L), Centre (C), Right (R) and Utmost Right (U_R) region of noisy images are in turn noise free images. Noises are identified using extended Kalman filter techniques and edge detection techniques. The proposed edge detection technique detects noise in the edges of the image. Once the noise is identified through our proposed canny edge detection operator using Fast Fourier Transform technique, then we compute the noise level in the image through the Extended Kalman Filter techniques.

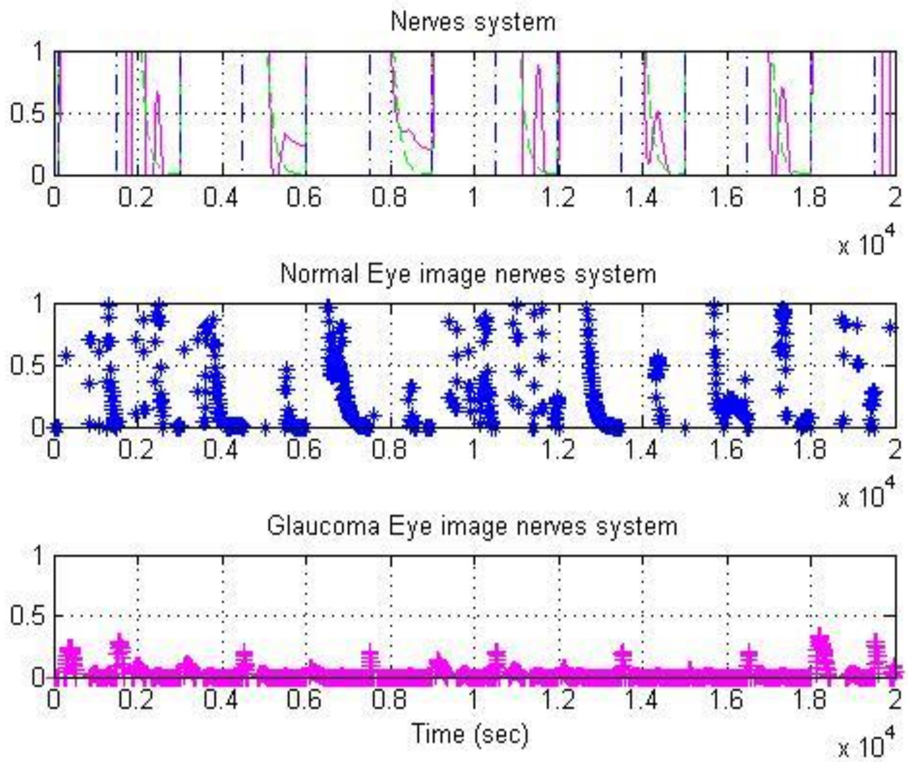


Figure 2 : Nerves system of normal eye and glaucomatous eye

We compared the normal eye image nerves system with general nerves system related to the normal eye and glaucoma eye image nerves system which is shown in the figure 2. The affected portion of the eye through glaucomatous and the normal eye are obviously identified through fuzzy expert system.

The fuzzy trapezoidal membership function for our proposed method is defined as follows:

$$\Delta_{UL} = |\mu_{UL_i} - \mu_{UL_j}|$$

$$\Delta_{L} = |\mu_{L_i} - \mu_{L_j}|$$

$$\Delta_{C} = |\mu_{C_i} - \mu_{C_j}|$$

$$\Delta_{R} = |\mu_{R_i} - \mu_{R_j}|$$

$$\Delta_{UR} = |\mu_{UR_i} - \mu_{UR_j}|$$

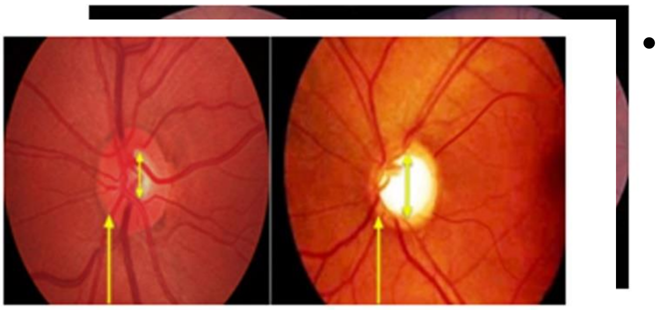
The embedded function can be written as:

$$T_r(F)\begin{cases} 0 & \\ \mu_{UL_i} - \mu_{UL_j} & UL_i < C_{ij} < UL_j \\ \mu_{L_i} - \mu_{L_j} & L_i < C_{ij} < L_j \\ \mu_{C_i} - \mu_{C_j} & C_i < C_{ij} < C_j \\ \mu_{R_i} - \mu_{R_j} & R_i < C_{ij} < R_j \\ \mu_{UR_i} - \mu_{UR_j} & UR_i < C_{ij} < UR_j \\ 1 & \text{Otherwise} \end{cases}$$

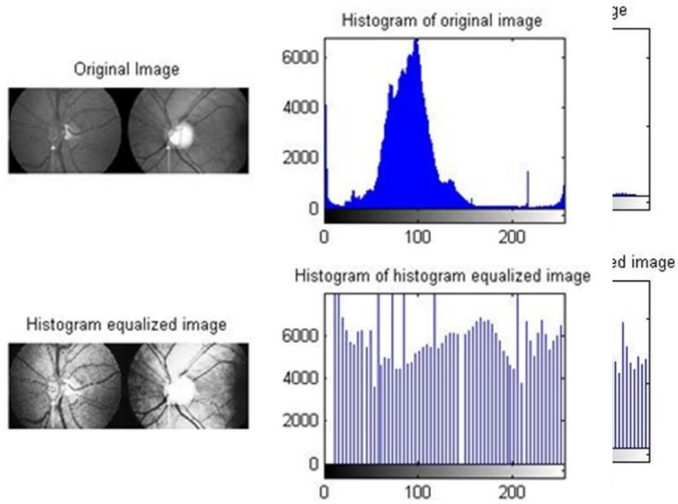
V Implementation of Fuzzy knowledge base expert system

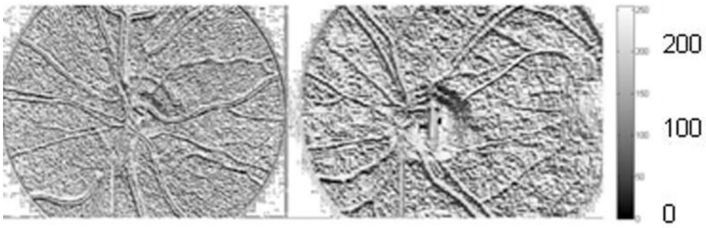
Fuzzy knowledge based expert system represented and process like a human being. It manipulates the concept of approximation in image processing. The simulation results are arrived through MATLAB. To implement our fuzzification concepts we took three difference types of normal eye images and glaucomatous eye images (diverse images) which are shown in the figures 3 - 5. Among these eye images we tested the following:

- Histogram of normal eye
- Histogram of glaucomatous eye
- Histogram equalized image of normal eye
- Histogram equalized image of glaucomatous eye
- Histogram of histogram equalized image of normal eye
- Histogram of histogram equalized image of glaucomatous eye
- Edge detection of normal eye
- Edge detection of glaucomatous eye
- Array of normal image eye dimensions and
- Array of glaucomatous image eye dimensions

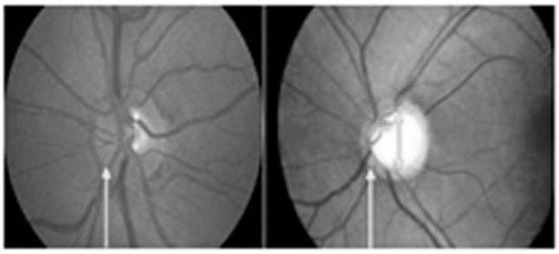


Normal Eye Glaucomatous eye

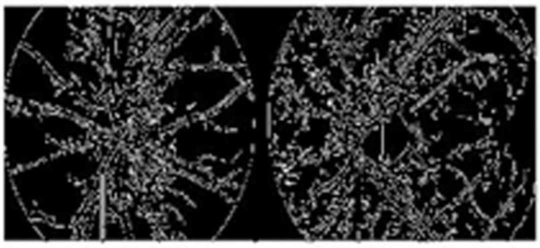




Array of normal eye image dimensions Array of Glaucomatous image dimensions



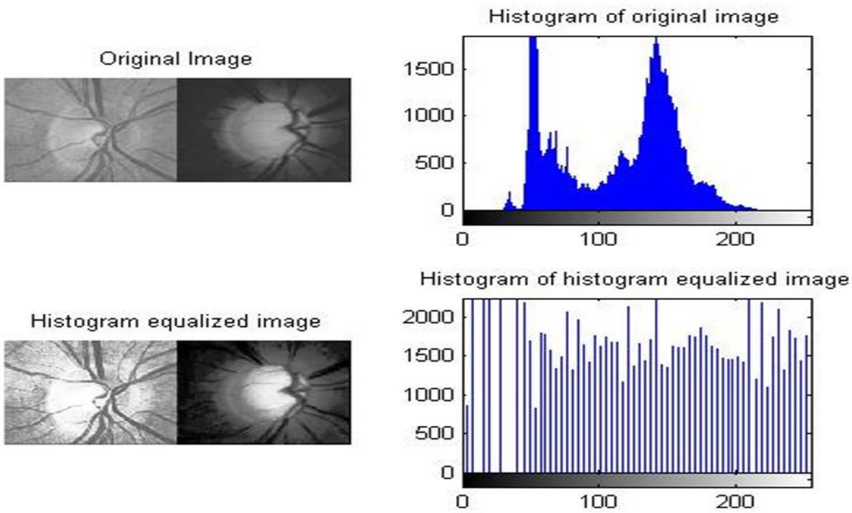
Normal Eye Glaucoma Eye



Edge Detection

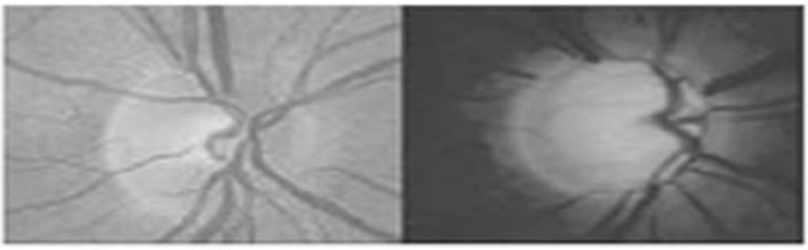
Figure 3 : Comparison of normal eye and Figure 4: Comparison of normal eye and (diverse)
glaucomatous eye using soft computing techniques glaucomatous eye using soft computing techniques

Normal Eye Glaucomatous eye



Array of normal eye image dimensions

Array of Glaucomatous image dimensions



Normal Eye Glaucoma Eye

Edge Detection

Figure 5: Comparison of normal eye and glaucomatous eye using soft computing techniques

The above simulations techniques have several steps for retinal fundus image processing. To get the optimal result we used edge detection method and convex hull concept to detect the glaucomatous eye.

VI Conclusion

Fuzzy knowledge based expert system was separately performed for glaucomatous and non-glaucomatous eye images. In this dissertation we analysed three different eyes which includes normal eyes and glaucomatous eyes (diverse stages). The soft computing techniques involved on seven different parts of the eye and arrived the optimal prediction through edge detection method and the noises are removed with the concepts of extended Kalman filter techniques. The array dimensions of optic nerves and the histogram of fundus images are arrived through MATLAB and conclude that these methodologies are efficient and accurate tool for the diagnosis of Glaucoma by means of soft computing techniques.

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