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Detection and Classification of Exudates in Diabetic Retinopathy

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Abstract: Diabetic retinopathy is one of the most common diabetic diseases that are caused by changes in the blood vessel of the retina. In some people with diabetic retinopathy blood vessels may swell and leak fluid. In some other people abnormal blood vessels may grow on surface of retina. Diabetic retinopathy is one of the complications caused by diabetes. As indicated by the name, diabetic retinopathy appears in the retina, which is the tissue responsible for vision in the eye. Since diabetic retinopathy causes changes in the eye, the disease may affect the vision. The work is aimed to develop an automated system to analyse the retinal images for extracting exudates which are primary signs of diabetic retinopathy. Hard exudates are small, yellow in colour or white waxy patches. The process mainly consists of two main phases. At the initial phase, exudates are detected using morphological image processing techniques, which includes elimination of optic disc and the detected exudates are classified using fuzzy logic algorithm. The fuzzy logic concept uses values in RGB colour space of retinal images, for the fuzzy set. The exudates detected are classified as normal, weak, hard exudates.

Keywords: Diabetic retinopathy; optic disc; exudates; morphological image processing; fuzzy logic.

I. INTRODUCTION

Diabetes is a group of metabolic diseases in which a person has high blood sugar either because the consistency does not make adequate insulin or because the cells do not respond to the insulin that is made. Diabetic related eye disease is a major cause of preventable blindness in the world. Diabetes can cause weakening in the body's blood vessels. It is a complication of diabetes, which can also affect various regions of the physical structure. When the diminished blood vessels have a high level of glucose in the retina, the sight will be obscured and can cause blindness eventual. This is known as Diabetic Retinopathy. Diabetic Retinopathy is one of the most common diabetic eye disease, which occurs when blood vessels in the retina changes. The blood vessels in the retina are very susceptible to dampening and can work through a series of modifications. When the blood vessels in the retina are damaged, these vessels swell and leak fluid. These modifications may be leaking or closure from the tiny blood vessels (known as capillaries) or the growth of weak, new capillaries that bleed very well. In some other cases, abnormal new blood vessels are grown on the surface of retina [3]. Diabetic Retinopathy is the most common diabetic eye disease which occurs due to damage of blood vessels in the retina and a leading cause of blindness in diabetic patients. Diabetic retinopathy is the main cause of blindness in America and over 99% countries. It is estimated to account for 12% of all the new cases of blindness in the United States each year. In Singapore, retinal disease accounts for more than half of the newly registered blindness with diabetic retinopathy as one of the primary contributors. It is calculated that approximately 10% of the population over the age of 40 are affected with diabetes and approximately 20% of this group will get some sort of diabetic complications in the optic. The symptoms of Diabetic Retinopathy include blurred vision, sudden vision loss in one eye, seeing rings around lights, black spots. Diabetic Retinopathy usually affects both eyes.There are two cases of diabetes: Type 1 is insulin dependent and Type 2 non-insulin dependent diabetes. All people with diabetes, both Type 1 and Type 2 are at the risk of Diabetic Retinopathy. Generally, diabetic retinopathy is classified into two main phases, namely Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetes Retinopathy (PDR) [7]. NPDR is the earliest stage of Diabetic Retinopathy. With the damaged conditions in blood vessels the retina begins to leak extra fluid and low amount of blood into the eye. In NPDR lesions in the retina include microaneurysms (small red points), retinal hemorrhages (tiny spots of blood that leak into retina), hard exudates (deposits of cholesterol or other fatty tissues from the stock that have leaked), and intra-retinal micro vascular abnormalities. The bearing of these wounds in various degrees determines whether NPDR is mild NPDR, moderate NPDR or severe NPDR. PDR mainly occurs when many of the blood vessels in the retina close, preventing enough blood flow. In an effort to furnish blood to the area where the original vessels remain closed, the retina responds by forming new blood vessels which are called neovascularisation. PDR cause more serious vision loss than NPDR because it involves both central and peripheral vision.PDR results in neovascularisation of retina, vitreous hemorrhages, pre-retinal hemorrhages.

The aim of the task is to create a system that detects hard exudates in a DR eye using fundus retinal images and form them as hard and weak exudates. Exudates are the elemental sign of Diabetic Retinopathy. If exudates are developed near the fundamental portion of your vision (macula), the central vision may be shortened. If the small retinal vessels close off (capillary closure or capillary drop out) the retina will become oxygen starved (ischemic). When this passes, white pieces of oxygen starved retina (cotton wool spots) may continue. This can contribute to the development of fresh blood vessels (neovascularization) which bleed and leak fluid easily. These vessels can result in scar tissue, which the vitreous can pull. This can have bleeding into the vitreous and/or detach the retina. Automatic early detection of exudates in retina can assist ophthalmologists to prevent the spread of the disease more efficiently. Exudates are yellow spots seen in the retina. They are lipid break-down products that are left behind after localized edema resolves. Exudates are of two types, namely hard exudates(cotton wool spots) and soft exudates. Hard exudates are small, yellow in colour or white waxy patches. When hard exudates encroach on the macula, vision is affected. Hard exudates are detected through morphological image processing techniques which also eliminate the optic disc. The motivation behind this paper is that exudates are the primary visible sign of DR disease and are instantly related to retinal edema and visual loss, and also one of the most important retina lesions detectable in retinal images. The exudates identified using morphological methods are separated out as hard and weak exudates using fuzzy logic algorithm. The hard exudates extracted using a fuzzy logic algorithm uses values in RGB colour space of retinal images to form fuzzy sets and membership roles. The fuzzy output is computed for hard exudates according to the proportion of the expanse of hard exudates.

II. LITERATURE SURVEY

Many important eye diseases as well as systematic diseases manifest themselves in the retina. The main reason of visual loss in people with diabetes is Diabetic Macula Edema (DME) which is common in type 2 diabetes. Diabetic Retinopathy is a complication caused by diabetes mellitus and the second most common cause of blindness and visual loss in the US. The exudates in the DR are caused by accumulation of proteins and lipids from blood leaking into the retina through damaged blood vessels. They seem as bright, reflective, heavy white/cream colored areas on the ophthalmoscope. There are rather a number of approaches reported on the subject area to detect the hard exudates. An automated analysis of fundus image is very much indispensable and will aid to facilitate clinical diagnosis. The various diseases that will affect eye are found out with the help digital fundus image. The primary principle behind this task is on detection of intraretinal fatty (hard) exudates, that are not just a principle sign of DR, but likewise an indication of the natural event of co-existent retinal edema and if present in the nuclear area, exudates are major players of vision loss in diabetic retinopathy.

An automated system for the spotting of various abnormalities due to diabetic retinopathy in retinal images was proposed by T. Vandarkuzhali in 2013 in the paper "Detection of exudates caused by diabetic retinopathy in fundus retinal image using fuzzy K means and neural network". An abstract idea of fuzzy logic and neural network is applied to distinguish the abnormalities in the fovea. These are assessed for normal as well as affected retinal images. In this paper the exudates due to diabetic retinopathy is identified using fuzzy K-means. By utilizing this software, automatic detection of exudates due to DR is achieved within a short span of time. The accuracy and efficiency is much better when compared to fuzzy C-means. Normal retinal images as well as affected images are used to experiment. This system is simple and efficient in extracting whether the picture is normal or abnormal state. [2]

Sophark in the paper "Automatic exudates detection from non-dilated diabetic retinopathy retinal images using fuzzy C-means clustering" have proposed FCM clustering method to detect exudates. As an initial step, contrast enhancement is used followed by providing information obtained from image features to a coarse segmentation routine using FCM clustering method. The image features include intensity, standard deviation on intensity, hue and the number of pixels. The optic disc is identified using entropy feature. An FCM clustering algorithm is applied to segmentation along with morphological reconstruction to obtain better segmentation results. The difference image is thresholded and reconstructed to obtain the last result. [5]

In the paper "Detection and classification of exudates using k-means clustering in color retinal images" exudates are detected using k-means clustering technique. In this paper, an efficient method to identify and classify the exudates as hard and soft exudates is presented. The retinal image in color space is pre-treated to get rid of interference. Next, blood vessel network is eliminated to facilitate detection and elimination of the optic disc. Optic disc is eliminated using Hough transform approach. The exudates are then detected using k-means clustering mander. Finally, the detected exudates are sorted as hard and soft exudates based on their edge energy and threshold. The recommned method has yielded good results. Although the Hough transformation can also be utilized to isolate the optic disc in retinal images, the resolutions are not accurate when its condition is not round. [7]

The paper “Enhancement of exudates for the diagnosis of diabetic retinopathy using fuzzy morphology” introduces a novel algorithm based on Fuzzy Morphology for the computer-assisted enhancement of exudates in fundus images of human retina for the diagnosis of diabetic retinopathy. Diabetic retinopathy is a frequent disease in diabetic people. The disease is diagnosed by the presence of exudates in the macular area. Here, we use Fuzzy Morphology for the enhancement of exudates. The fundus image is first changed to grayscale followed by a series of fuzzy erosion and fuzzy dilation (morphological closing operation) with a diamond shaped structuring element. In the end, the resulting picture is appended to the original image to transform into enhanced one. Experiments were done on a database of variety of fundus images which is normal and abnormal. The experiments led to impressive results and the pictures were raised for easier clinical examination. [8]

Exudates are a visible sign of diabetic retinopathy, which is the major source of blindness in patients with diabetes. If the exudates expand into the macular area, vision loss can happen. Automated early detection of the presence of exudates can assist ophthalmologists to prevent the spread of the disease more efficiently. Hence, the detection of exudates is an important diagnostic task. The catching of the optic disc is essential in the exudates detection process since they both are alike in terms of color, dividing line, etc. In the paper proposed by M.Ramaswamy in 2011 a study of various techniques like morphological approach, region growing approach, fuzzy, c-means clustering technique, k-means clustering techniques is made to suggest a technique for automatic early identification of diabetic retinopathy. These methods are implemented and their operations are assessed based on various metrics like sensitivity, specificity etc. These algorithms are proven on a small image data base and their accuracies are analyzed with regard to expert ophthalmologist’s hand-drawn ground-truths. [10]

III. Proposed System

The project proposes to find the hard exudates in retinal images using morphological image processing and fuzzy logic algorithm is applied for classification of detected exudates. The suggested method is established utilising the morphological image processing. At the initial phase, the exudates are identified using mathematical morphology that includes elimination of the optic disc. The hard exudates are extracted using an adaptive fuzzy logic algorithm that uses values in the RGB color space of the retinal image to form fuzzy sets and membership functions.

A. Eye Imaging

Initially, retinal fundus image is obtained for abnormality analysis. The retinal fundus photograph is widely used in the diagnosis and treatment of various eye diseases such as diabetic retinopathy and glaucoma. There are various imaging systems/techniques available for analysis optic nerves and retina. One such imaging technique is addressed as "Retinal Photography" or "Fundus Imaging". This technique is used to take photographs of the retinal area for diagnostic purposes. Fundus Cameras are used for this function and the retinal photographs obtained using them are named as 'Fundus Images or Fundus Photographs'. Fundus Photography is used to record the condition of these structures in order to document the presence of disorders and monitor their change over time. Retinal Photography is becoming a must in Optometric practices \cite{10}. It is not just a tremendous practice builder, but essential in the management of several eye diseases especially glaucoma's. Photographic documentation of diabetic retinopathy patients helps the eye doctors to keep a database of the advancement of the disease. Several cases of eye imaging that are used by ophthalmologists for examining different features of the eye and examine problems connected to the optic. A fundus camera or retinal camera is a specialized low power microscope with an attached camera designed to shoot the inner surface of the eye, which includes retina, optic disc, macula, and posterior pole (i.e. the fundus). Fundus cameras are used by optometrists, ophthalmologists, and trained medical professionals for monitoring progression of a disease, diagnosis of a disease (combined with retinal angiography), and also in screening programs, where the photos can be dissected afterwards. A fundus camera provides an upright, enlarged view of the fundus. A typical camera views 30 to 50 degrees of retinal field, with a magnification of 2.5x, and allows some modification of this relationship through zoom or auxiliary lanes from 15 degrees, which provides 5x magnification to 140 degrees with a wide angle lens which enlarges the image by half. Since the instruments are complex in design and difficult to cook up to clinical standards, only a few producers exist: Topcon, Zeiss, Canon, Nidek, and Kowa. Generally the fundus camera is of two types, which is based on the dilated pupil of the eye. They are Mydriatic Fundus Camera (requires dilation of the pupil). E.g.: Topcon TRC-50DX Retinal Camera and Non-mydriatic (no dilation of the pupil is required) Fundus Camera. E.g.: Topcon TRC-NW8 Retinal Camera. The camera used for image acquisition here is TOPCON FUNDUS CAMERA TRC 50 DX.

B. Morphological Operations

The most basic morphological operations are dilation and erosion [10]. An indispensable component of the dilation and erosion operations are the structuring element used to examine the input picture. A structuring element is a matrix consisting of only 0's and 1's that can take in any arbitrary form and size. The pixels with values of 1 define the neighborhood. Morphological reconstruction can be thought of conceptually as repeated dilations of an image, known as the marker image, until the contour of the marker image fits under a second icon, called the mask icon. Morphological reconstruction processes one image, called the marker, based along the characteristics of another picture, called the mask.

C. Methodology

Initially the RGB color image obtained as a fundus image is changed over to HIS image. The I-band of the fundus image is used for further processing since the optic disc and exudates have high saturation values of intensity channel. So the fundus image is transformed into HSI image and intensity channel of HIS image taken for further processing. HSI color space (Hue, Saturation, and Intensity) is more appropriate since it lets the intensity component to be branched from other two color components. The fundus RGB image conversion to HSI is straight forward since RGB image to grayscale conversion is not singular [1]. Then median filtering is employed to the intensity band of the image for noise reduction. Median filtering is a non-linear process used to remove noise from images. It is widely practiced as it is very efficient at getting rid of noise while preserving edges. It is especially efficient at getting rid of salt and pepper noise. Then a Contrast Limited Adaptive Histogram Equalization (CLAHE) is employed for contrast enhancement to prevent over saturation of the homogeneous areas in retinal images. CLAHE operates in small areas in the image [4]. The contrast of the image is enhanced with histogram equalization. Contrast enhancement is an important factor in image enhancement. The techniques based on histogram are one of the most important image processing techniques. Histogram equalization tends to vary the luminosity of the picture.The equation for the Gaussian function in two dimensions is

$$G(x,y) = \frac{1}{2\pi\sigma^2} e \frac{-x^2 + y^2}{2\sigma^2}$$

'X' is the distance from the origin in the horizontal axis; 'y' is the distance from the origin in the vertical axis. s is the standard deviation of the Gaussian distribution. This completes the pre-processing step.

Later on the pre-processing techniques next step is the elimination of optical disc. The optic disc is believed one of the primary characteristics of a retinal fundus image for automatic detection of exudates. The Optic Disc (OD) is the most promising feature of the normal funds, and it owns about a vertically slightly oval (oval) shape. In colored fundus images, the OD appears as a bright yellowish or white region. The OD is considered the exit part of the blood vessels and the optic nerves from the retina, also characterized by a relatively pale view owing to the nerve tissue underlying it [10]. Measured relative to the retinal fundus image, it occupies almost one seventh of the total picture. Alternatively the OD size varies from one individual to another, filling approximately one tenth to one fifth of the image. For the elimination of optic disc, a closing operation with flat disc shape as structuring element is applied to the picture. This does away with the high contrast blood vessels. Optic disc is eliminated before detecting the exudates as optic disc and exudates contain same color and saturation. After the closing operation, the image is binarized using thresholding techniques namely p-tile method and Niblack's method [13].

A Niblack's algorithm is a local thresholding method based on the computation of the local mean and local standard deviation over a specific window size just about each pixel position. The local threshold at any pixel (i, j) is counted as T (i,j) = m(i,j)+K.s(i,j) Where m (i,j) and s(i,j) are the local sample mean and variance respectively. The size of the local region (window) is dependent upon the application. The value of weight 'K' is used to check and adjust the result of standard deviation due to object features. Niblack algorithm suggests values of K to be 0-2. The Niblack's method requires optimum selection of weight 'K'. In this system a weight of 1.3 is used in Niblack's method for thresholding.

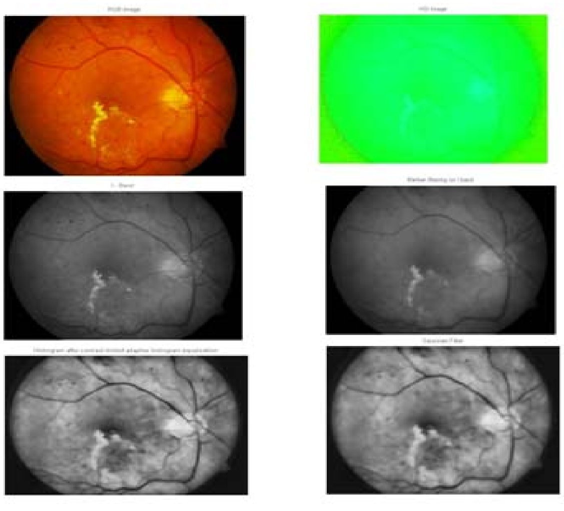

Figure 1 Pre processing

The area containing the optic disc is more hopeful than other parts in the retinal picture. The optic disc occupies ~2% of bright region in fundus image. This percentage is used to perform the p-tile thresholding method to obtain the binary images. P-tile is shorter for percentile. The P - tile method is one of the earliest thresholding method based on the gray - level histogram. It is assumed that objects in an image are brighter than the background and occupy a fixed percentage of the area. This fixed percentage of the picture field is known as P%. The largest connected component which provides a high value of compactness among these methods is considered as optic disc. The binary image obtained after Niblack's method provides high compactness for the large circular component. This eliminates the optic disc.

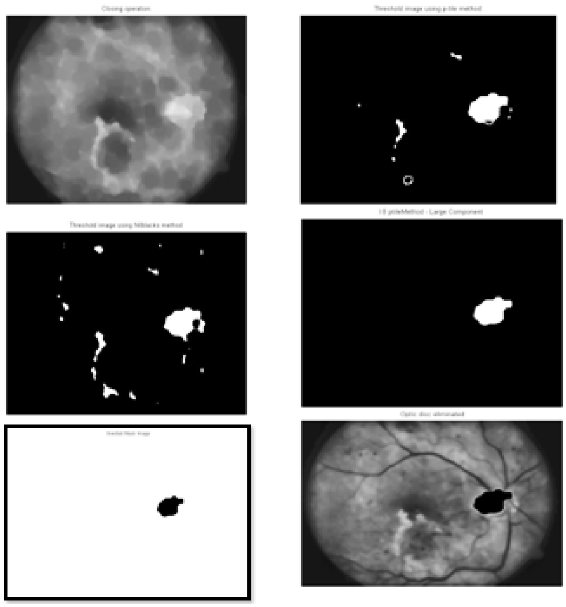

Figure 2 Optic Disc Eliminated

Directly for the detection of exudates, a closing operation with flat disc shape as structuring element is employed with a radius of 16 pixels after applying these thresholding techniques. This does away with the high contrast blood vessels in fundus image. Then the standard deviation of the image is calculated. And so the triangle thresholding method is employed to draw out every minute bright region together with borders of the large bright region. Then the unwanted borders are taken out by taking off the dilated optic disc region from the threshold image. As the next step, flood filling is carried out on all holes in order to create a marker image for morphological reconstruction. Then the difference image between the resulting image and an intensity band of the original image is taken for thresholding and the output of this threshold image is super-imposed on the original RGB image to extract exudates.

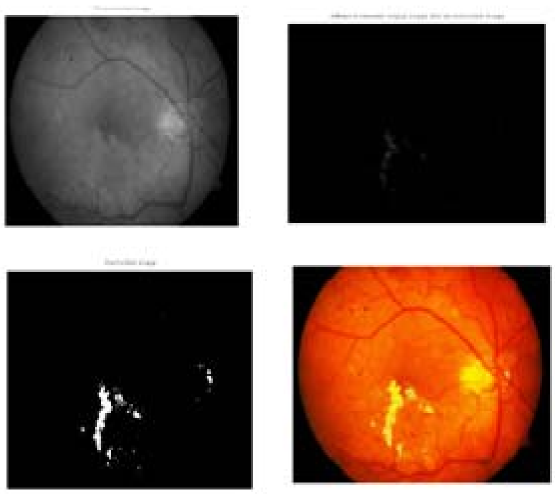

Figure 3 Exudates Detected

D. *Graphical User Interface*

A graphical user interface (GUI) is a pictorial interface to a program. A GUI can make programs easier to use by providing them with a consistent appearance and controls like push buttons, list boxes, sliders, menus and so forward. The GUI should behave in an intelligible and predictable way. A graphical user interface provides the user with a familiar environment in which to operate. This environment contains push buttons, toggle buttons, lists, menu, text boxes. However GUI's are harder for the programmer because a GUI-based program must be prepared for mouse clicks for any GUI element at any time. The principal elements required to create a MATLAB Graphical user interface are Components, Figures, Call backs. An interactive GUI is included in the program to show the working.

Figure 4 GUI

IV. CLASSIFICATION OF EXUDATES

In the proposed scheme, the detected exudates are classified using fuzzy logic. There is a unique membership function MF associated with each input parameter. The RGB value of retinal fundus image is used to form the fuzzy set and membership functions. It uses red, green and blue values of pixel as three input values x_r, x_g, x_b for the fuzzy interference system giving a single output. To calculate the output x_r, x_g, x_b the fuzzy interference system provides the degree of membership function to the output variable X_{out}. De-fuzzification based on centeroid method is used for the identification of hard exudates. The variables x_r, x_g, x_b and X_{out} are represented using the Gaussian member function.

$$\mu(x) = e^{-((Ci-x)^2(2\sigma i^2))}$$

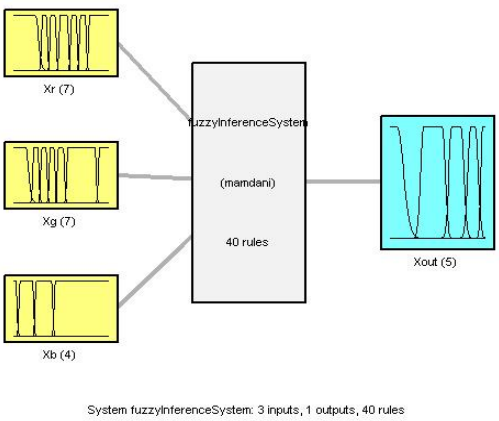

Figure 5 Fuzzy Interference System

In the proposed system fuzzy logic determines the fuzzy output for a given input set x_r, x_g, x_b corresponding to red,green and blue channels. Seven fuzzy sets for the input variable x_r, x_g and four fuzzy sets for the input variable x_b were selected for the input variable color space values. Five fuzzy sets were derived to represent the output variable. Fuzzy output is counted for all picture elements in every exudates in retinal images. The area is thought to be hard exudates if average fuzzy value is > 0.25. Based on the percentage of an area of hard exudates, the fuzzy output is calculated. The exudates detected are classified as hard exudates using fuzzy rules. The fuzzy rule is used to detect hard exudates. By putting a crisp value for each hard exudate, we classify each exudates as hard exudates. Founded on this crisp value, a value is reckoned for all exudates according to the ratio of its region. An exudate having a crisp output value > 0.25 is considered as hard exudates. The crisp logic is created according to the member function of linguistic variable X_{out}. The fuzzy output less than 0.25 is considered as very tiny hard exudates [1]. The exudates detected in retinal images are categorized as soft exudates, weak hard exudates, medium hard exudates, hard exudates and severe hard exudates.

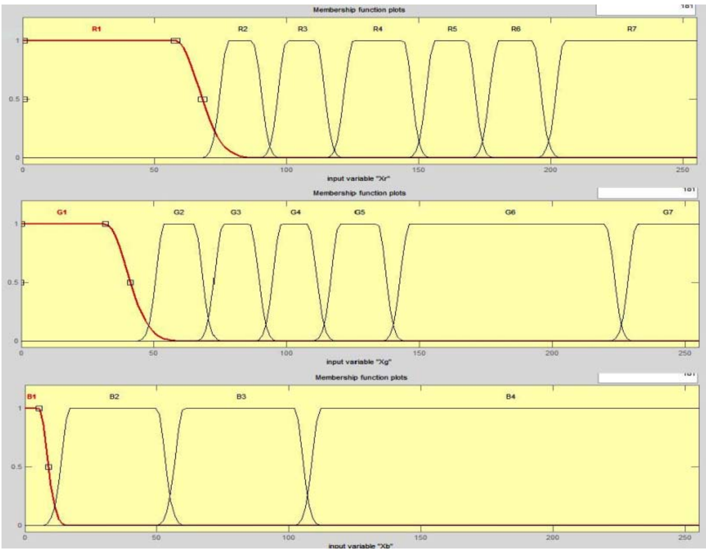

Figure 6 Input Member Functions

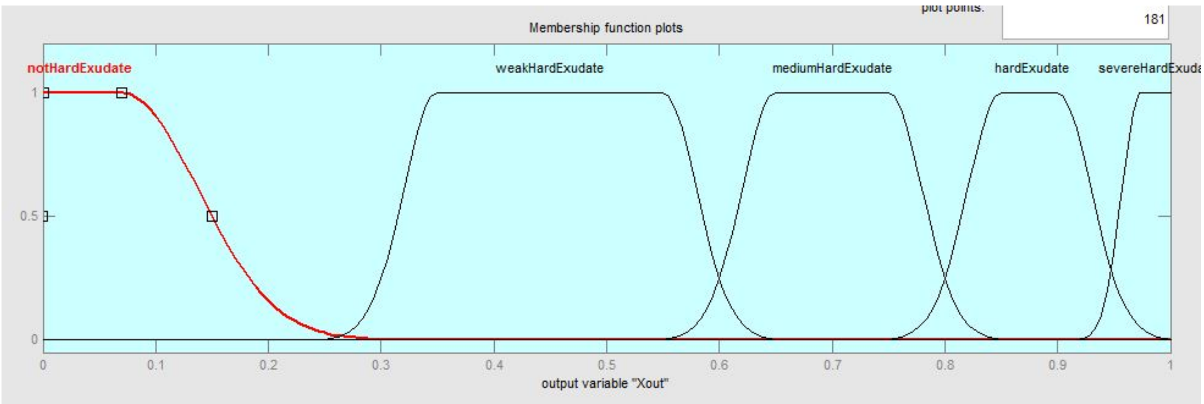

Figure 7 Output member functions

V. RESULT AND CONCLUSION

Modern scientific databases and web databases maintain large data. These real-world databases contain over hundreds or even thousands of relations and attributes. Query forms are not able to satisfy various ad-hoc queries from users on those databases. DQF, a novel database query form interface, used to dynamically generate query forms. The dynamic query form generation approach which helps users dynamically generate query forms. The key idea is to use a probabilistic model to rank form components based on user preferences. Ranking of form components also makes it easier for users to customize query formkkk.

For testing the proposed system images were chosen from the publicly available Diabetic Retinopathy dataset DIARETDB0 and DIARETDB1.Also images were taken from the hospital Dr. Tony Fernandez super specialty eye hospital, Aluva. The fundus images are obtained using TOPCON Fundus camera TRC 50 DX captured with a 50° field-of-view. The pictures with a size of 1500 x 1152 pixels are used to prove the proposed technique using Matlab version 7.10. The exudates detected are classified as hard exudates using fuzzy rules. In this approach, we first classify each exudate as hard exudates by assigning a crisp value for each hard exudate. We have considered an exudate having a crisp output value > 0.25 as a hard exudate. This crisp logic is made according to the MF of linguistic variables of X_{out}. With this logic, an exudate is at least a weak hard exudate if the output crisp value of an exudate becomes >0.25. We found the fuzzy output less than but very close to 0.25 for very tiny hard exudates. As such tiny hard exudates and soft exudates exhibit similar colour intensities, it is extremely difficult to separate both these types of exudates and as a result, at certain times, the technique identifies these very tiny hard exudates as non-hard exudates. In this research, better results were obtained using overlapping Gaussian combination MFs. The fuzzy output values for different points of overlap between the MFs are checked and it provided some inaccurate results for low levels of overlap between the MFs. The fuzzy output values of very tiny hard exudates have decreased by more than the expected fuzzy output values for such low levels of overlapping MFs with tiny hard exudates being identified as non-hard exudates. The fuzzy output values of non-hard exudates (except soft exudates) have increased, whereas the fuzzy output values of weak hard exudates have decreased for low levels of overlap between the MFs. Therefore, such non-overlapping MFs may produce inaccurate results confirming the importance of having overlapping MFs for detection of hard exudates.

The exudates in retinal images are classified into soft exudates, weak hard exudates, medium hard exudates, hard exudates and severe hard exudates derive the fuzzy sets and proper linguistic variables. Seven fuzzy sets for the input variables xr and xg and four fuzzy sets for the input variable DB were selected to interpret each of the input variable's color space values. Later, five fuzzy sets were derived to represent the output variable. We have experimented with different types of MFs which represents the level of membership of linguistic variables within their linguistic terms and found Gaussian combination MFs leading to more accurate solutions than other MFs. The one sided Gaussian combination MFs to represent the linguistic variables x_r, x_g, x_b and x_{out} because it is required to indicate full membership within the linguistic conditions of a certain range of values. These areas receive a substantial point of truth values corresponding to linguistic terms.

Diabetic retinopathy eye diseases are the main cause of vision loss and their prevalence is set to continue rising. Current methods of detection and assessment of diabetic retinopathy are manual, expensive,time consuming and require trained ophthalmologists. Automatic Diabetic retinopathy eye diseases detection would be helpful for diabetic retinopathy screening process. Early detection can potentially reduce the risk of blindness. This research offers a novel technique to identify exudates using morphological methods and categorize these exudates into hard and non-hard exudates using the principle of fuzzy logic. The effectiveness of this method is the ability to decide whether each exudate is hard exudate or not, on an individual basis. We have used the intensity band in the HIS image at this point. As the fundus image generally contains a high amount of noise, different pre-processing techniques can be used for noise suppression and enhancing features to equalize regions showing uneven contrast. The technique is fully automated and can be utilized to a database of retinal images without altering any parameters during performance of the algorithm. We have used images from a database available in the public sphere for the experiments shown in this report. It is prudent, however, to verify this technique using other databases containing DR images. Also, the work needs to be improved to detect exudate pixels having very low intensity values.

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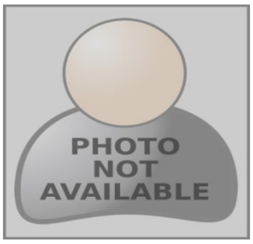

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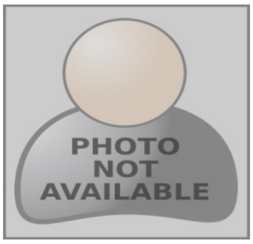

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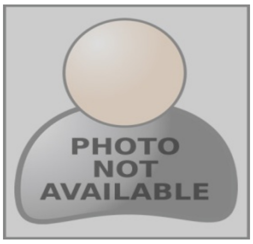

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