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Automated Detection of VascularAbnormalities in Diabetic Retinopathy

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***Abstract*---This paper uses the process and knowledge of image processing to diagnose diabetic retinopathy from images of retina. The Pre-Processing stage equalizes the uneven illumination associated with fundus images and also removes noise present in the image. Blood vessel extraction step extracts the blood vessels from pre-processed fundus image while the micro aneurism detection and exudate detection stage detects the main abnormalities of diabetic retinopathy micro aneurism and exudates respectively. Calculation of micro aneurism area and exudates area were useful to decide the stage of the disease. The stage of the disease considered as NORMAL, MILD and SEVERE. In addition to diagnosis of Diabetic Retinopathy (DR), Graphical User Interfaces (GUI's) were also developed during this work to make useful to the ophthalmologist. The algorithm was tested with a separate set of 89 fundus images from DIRETDB1 database. From this, Sensitivity, Specificity and Accuracy were determined by compare with ground truth image provided in database. Sensitivity (classify abnormal fundus images as abnormal), specificity (classify normal fundus image as normal), and Accuracy were calculated by the proposed algorithm. The proposed method successfully classified the subjects into normal DR, mild DR, and severe DR with Accuracy, Sensitivity and Specificity of 99.92%, 99.93%, and 99.84% were reported respectively**.

Keywords-Diabetic Retinopathy, Fundus Image, Digital Image Processing, Blood vessel extraction, Micro aneurism, Exudates, Retina, Classifier, Graphical User Interface.

I. INTRODUCTION

The energy required by the body is obtained from glucose which is produced as a result of food digestion. Digested food enters the body stream with the aid of a hormone called insulin which is produced by the pancreas, an organ that lies near the stomach. During eating, the pancreas automatically produces the correct amount of insulin needed for allowing glucose absorption from the blood into the cells. In individuals with diabetes, the pancreas either produces too little or no insulin or the cells do not react properly to the insulin that is produced. The buildup of glucose in the blood, overflows into the urine and then passes out of the body. Therefore, the body loses its main source of fuel even though the blood contains large amounts of glucose.

The effect of diabetes on the eye is called Diabetic Retinopathy (DR). It is known to damage the small blood vessel of the retina and this might lead to loss of vision. Abnormalities associated with the eye can be detected mainly by Micro aneurysms, hard exudates, and Soft exudates. Micro aneurysms are the first clinical abnormality to be noticed in the eye. Hard exudates are one of the main characteristics of diabetic retinopathy and can vary in size from tiny specks to large patches with clear edges. Soft exudates are often called 'cotton wool spots' and are more often seen in advanced retinopathy.

The disease level is classified by proposed method based on the area of micro aneurism and exudates into three stages viz: Normal Diabetic Retinopathy, Mild Diabetic Retinopathy and Severe Diabetic Retinopathy. Normal diabetic retinopathy represents no abnormalities are present. Mild diabetic retinopathy represents Micro aneurisms are present. Severe diabetic retinopathy represents both micro aneurisms and exudates are present

This research work is one of the method of applying digital image processing to the field of medical diagnosis in order to lessen the time and stress undergone by the ophthalmologist and other members of the team in the screening, diagnosis and treatment of diabetic retinopathy.

II. PARAMETRIC APPROACH

There are many Diabetic retinopathy detection Algorithms. In this paper we mainly consider

- Morphological operation for Segmentation and Abnormality detection.

Morphological operations play a key role in digital image processing with special application in the field of machine vision and automatic object detection. The morphological operations include dilation, erosion, opening, closing and skeletonization etc.

A. Dilation: Dilation is a process that thickens objects in a binary image. The extent of this thickening is controlled by the Structuring Element (SE) which is represented by a matrix of 0s and 1s.Disk shaped structuring element is used for detection of blood vessels, micro aneurisms and exudates detection.

Mathematically, dilation operation can be written in terms of set notation as below

$$A \oplus A_s = \{z | (A'_s)\, z \cap A \neq \Phi\} \qquad (1)$$

Where Φ is an empty element and A_s is the structuring element. The dilation of A by A_s is the set consisting of all structuring element origin locations where the reflected and transmitted A_s overlaps at least some portions of A.

B. Erosion: Erosion shrinks or thins the objects in a binary image by the use of structuring Element. The mathematical representation of erosion is as shown below.

$$A \Theta A_s = \{z | (A_s)\, z \cap Ac \neq \Phi\} \qquad (2)$$

C. Opening and Closing: In image processing, dilation and erosion are used most often and in various combinations. An image may be subjected to series of dilations and or erosions using the same or different SE. The combination of these two principles leads to morphological image opening and morphological image closing. Morphological opening can be described as an erosion operation followed by a dilation operation. Morphological opening of image A by B is denoted by AoB, which is erosion of A by B followed by dilation of the result obtained by Y closing and opening.

$$AoB = (A \oplus B)\, \Theta B \qquad (3)$$

$$A \bullet B = (A \Theta B) \oplus B \qquad (4)$$

Morphological closing can also be described as dilation operation followed by erosion operation. Morphological Closing of Image A by B is denoted by A•B, which is dilation of A by B followed by erosion of the result obtained by B.

D. Skeletonization: Skeletonization is another way to reduce binary image objects to a set of thin strokes that can display important information about the shape of the original objects. Skeletonization is similar to thinning, except that it maintains more information about the internal structure of objects with it being 1 pixel thick.

III METHODOLOGY

This Proposed system mainly consists of six steps as shown in the Flow diagram of the project.

A. Image Pre-processing

Fundus images initially Pre-processed to solve the uneven illuminations so that the segmentation is easier. Pre-processing step includes Green channel extraction, and Adaptive histogram equalization. Green channel image extracted by performing rgb to gray conversion Adaptive histogram equalization gives the image with even illumination.

B. Blood vessel extraction

Morphological operations are applied to the preprocessed input image to extract blood vessels followed by optic disk detection and elimination. Empirically, ball shaped structuring element of size 8 is used to detect the blood vessels. Due to elimination of optic disk, the blood vessels in it are also lost; hence morphological reconstruction is applied to retrieve the lost blood vessels. At this stage, segmentation is performed to eliminate other features like micro aneurysms and exudates. Finally, the area of the blood vessels is calculated. The blood vessel covered area calculated by counting the white (value 1) pixels in total image area.

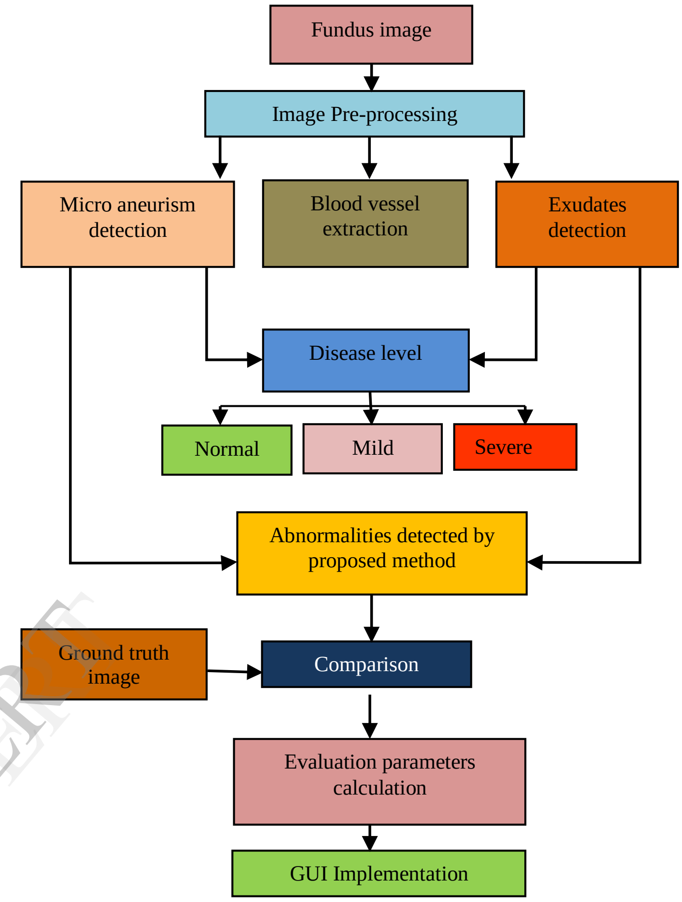

Fig.1.The Project flow.

C. Micro aneurism detection

The edge detection is performed on pre-processed image by using canny edge detector as it is used to detect edges in a very robust manner. Noise and other non-micro aneurysm features like exudates are eliminated by applying thresholding technique. Morphological operations with disk shaped structuring element of size 6 are used to eliminate blood vessel network. Obviously, normal retina does not contain micro aneurysms. Mild and Severe diabetic retinopathy stage contains micro aneurysms. The area covered by micro aneurism is calculated.

D. Exudates detection

To facilitate exudates detection, the optic disc is located and eliminated. Thresholding and morphological operations are then applied to detect the exudates. Obviously, normal retina does not contain exudates. Severe diabetic retinopathy stage contains exudates.

E. Disease level

The total area covered by the micro aneurism and exudates is calculated separately. Based on these areas the stage of the disease is decided as NORMAL, MILD or SEVERE based on following table.

Table 1: Disease level based on exudates and micro aneurism area

Area of Micro aneurism(A_m)	**Area of Exudates(A_e)**	**Stage of Disease**
A_m =0	A_e =0	NORMAL
A_m>0	A_e =0	MILD
A_m>0	A_e>0	SEVERE

E. Evaluation parameters calculation

Evaluation parameters considered in diabetic retinopathy are sensitivity, specificity and accuracy. These parameters are calculated by comparing detected abnormalities with ground truth image collected from database.In the proposed method the performance evaluation is done through statistical analysis, for this first calculate True Positive, False Positive, False Negative and True Negative by comparing abnormality detected by proposed method and ground truth image got from database. From this, Sensitivity, Specificity and Accuracy are calculated.

i). True Positive

True positive represents number of abnormal pixels correctly detected.

Algorithm for computing True positive
1. Read abnormality detected image I by proposed method.
2. Read ground truth of the image T from the database.
3. Find the size of the image, p as row and q as column.
4. Compare each pixel of image I, ground truth T and calculate the true positive as follows.

T_P=0
For i=1: p
For j= 1: q
If I (i, j) =1 and T (i, j) =1 then
$T_P = T_P + 1$
5. Save True positive (T_P) value.

ii). True Negative

True negative represents number of abnormal pixels detected as non-abnormal pixels.

Algorithm for computing True negative
1. Read abnormality detected image I by proposed method.
2. Read ground truth of the image T from the database.
3. Find the size of the image, p as row and q as column.
4. Compare each pixel of image I, ground truth T and calculate the true negative as follows.

T_n=0
For i=1: p
For j= 1: q
If I (i, j) =0 and T (i, j) =0 then
$T_n = T_n + 1$
5. Save True negative (T_n) value.

iii). False Positive

False positive represents number of non-abnormal pixels correctly detected.

Algorithm for computing false positive
1. Read abnormality detected image I by proposed method.
2. Read ground truth of the image T from the database.
3. Find the size of the image, p as row and q as column.
4. Compare each pixel of image I, ground truth T and calculate the false positive as follows.

F_p=0
For i=1: p
For j= 1: q
If I (i, j) =1 and T (i, j) =0 then
$F_p= F_p + 1$
5. Save false positive (F_p) value.

iv). False Negative

False negative represents number of abnormal pixels not detected.

Algorithm for computing false negative
1. Read abnormality detected image I by proposed method.
2. Read ground truth of the image T from the database.
3. Find the size of the image, p as row and q as column.
4. Compare each pixel of image I, ground truth T and calculate the false negative as follows.

F_n=0
For i=1: p
For j= 1: q
If I (i, j) =0 and T (i, j) =1 then
$F_n = F_n + 1$
5. Save false negative (F_n) value.

Evaluation parameters calculated by the formulae given below.

Sensitivity is the percentage of the actual abnormal pixels that are correctly detected. Specificity is the percentage of non-abnormal pixels is detected as non-abnormal.

$$\text{Sensitivity} = \frac{T_P}{T_P+F_n} \quad (5)$$

$$\text{Specificity}= \frac{T_n}{T_n+F_p} \quad (6)$$

$$\text{Accuracy}= \frac{T_P+T_n}{T_P+F_n+T_n+F_p} \quad (7)$$

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IV. ANALYSIS AND RESULTS

Fundus image is pre-processed by two steps:

- Green component extraction
- Adaptive histogram equalization

The pre-processing stage includes Green channel extraction, Adaptive histogram equalization. Original colour image is converted into Green component image in colour space conversion stage. Adaptive histogram is used to improve the image contrast. The blood vessels are extracted from pre-processed image. The corresponding outputs are shown in Fig 2.

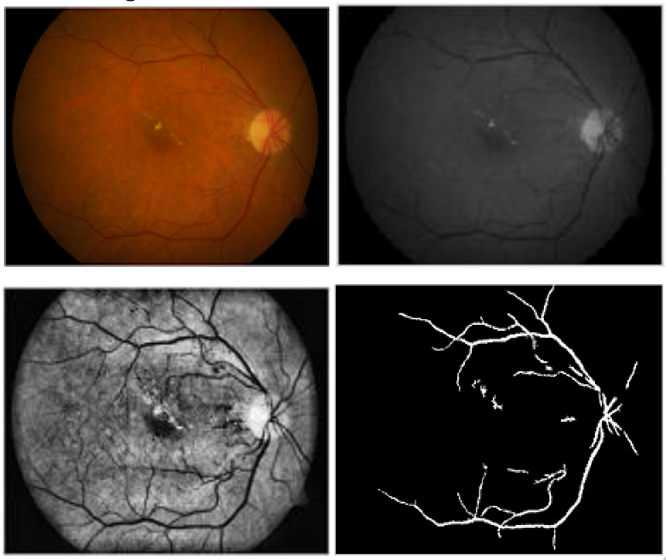

Fig.2.Pre-processing and Blood vessel extraction a) Original image b) Green component image c) Adaptive histogram equalized image d) Blood vessel extracted image.

Exudates detection was done using morphological approach. The result of Exudates detection and micro aneurism detection is as shown in Fig.3.

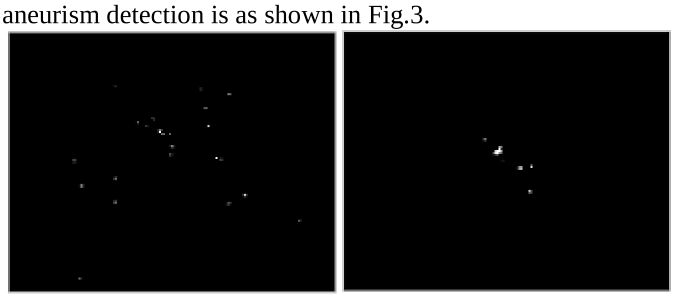

Fig.3. Abnormality detection: a) Micro aneurism b) Exudates detection

TABLE I: Disease level based on exudates and micro aneurism area

Area of Micro aneurism(A_m)	**Area of Exudates(A_e)**	**Stage of Disease**
$A_m = 0$	$A_e = 0$	NORMAL
$A_m > 0$	$A_e = 0$	MILD
$A_m > 0$	$A_e > 0$	SEVERE

The total area covered by the micro aneurism and exudates is calculated separately. Based on these areas the stage of the disease is decided as NORMAL, MILD or SEVERE based on TABLE I.

The result is optimal for highest sensitivity, Accuracy and specificity's value. These Evaluation parameters can be calculated by taking ground truth image from database as reference. Adding micro aneurism detected and exudates detected image we get total abnormalities detected by proposed method. This image is compare with ground truth image and calculated the Accuracy, Sensitivity and Specificity.

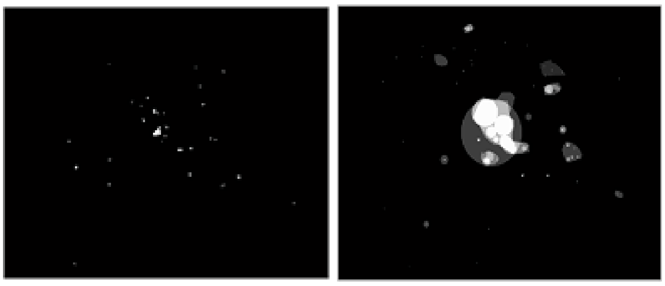

Fig.4. Abnormalities detected by: a) Proposed Method b) Ground truth image from database.

Evaluation parameters for ten images are calculated inTABLE II .

TABLE II: Evaluation parameter calculation for set of images

Sl No	**Image name**	**Sensitivity**	**Specificity**	**Accuracy**	**Stage of decease**
1	image01	99.97%	99.80%	99.94%	Severe DR
2	image02	99.97%	99.89%	99.95%	Severe DR
3	image03	99.88%	99.98%	99.91%	Mild DR
4	image05	99.85%	99.94%	99.90%	Severe DR
5	image06	99.95%	99.98%	99.96%	Severe DR
6	image07	99.85%	99.99%	99.91%	Severe DR
7	image08	99.93%	99.90%	99.92%	Severe DR
8	image28	99.99%	99.27%	99.99%	Severe DR
9	image85	99.96%	99.82%	99.93%	Mild DR
10	image89	99.99%	98.85%	99.87%	Severe DR

Comparing proposed method with existing method by taking average of evaluation parameters obtained in TABLE II is shown in TABLEIII.

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TABLE III: Comparison with existing methods

Methods	**Evaluation parameters**		
	Sensitivity	***Specificity***	***Accuracy***
FCM clustering with MR	92.6%	92.92%	92.49%
Neural network	93%	94%	93%
Proposed method	99.93%	99.84%	99.92%

Results obtained in Graphical User Interface (GUI).

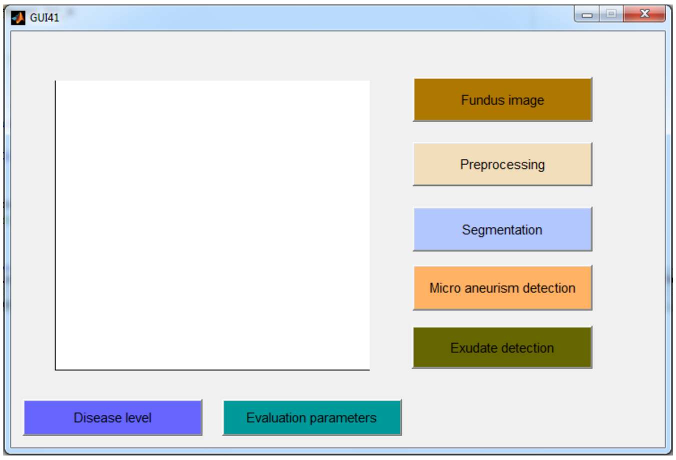

Fig.5. MATLAB based GUI

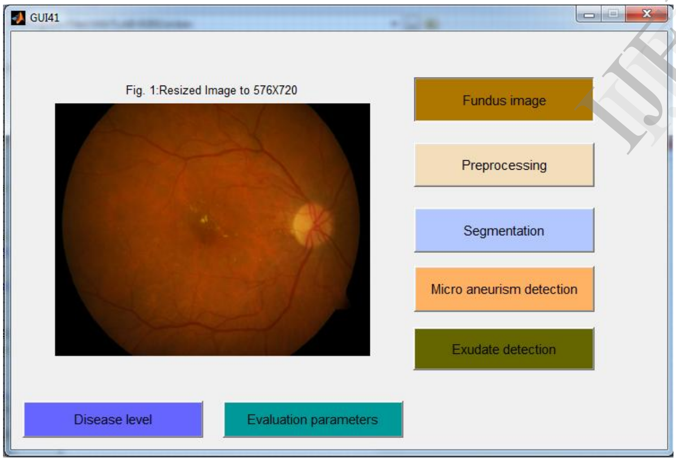

Fig.6. Original image

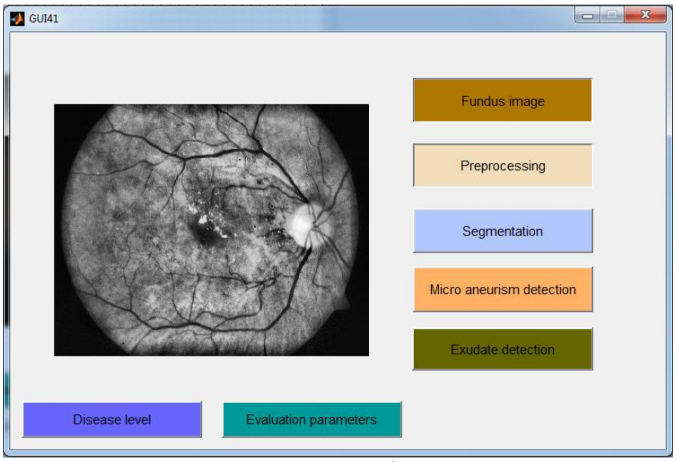

Fig.7. Pre-processed image

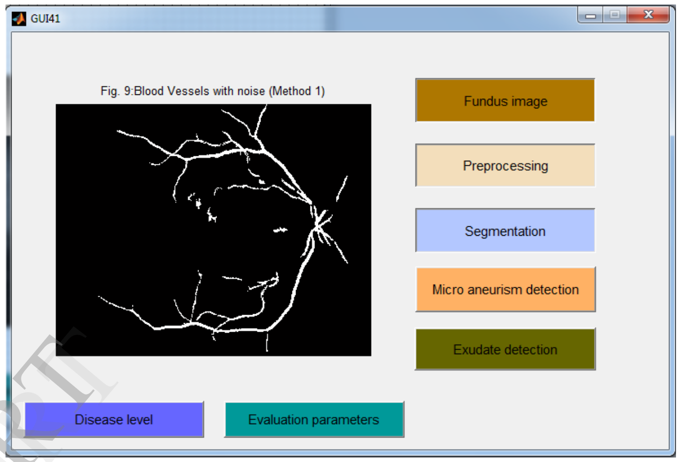

Fig.8. Extracted blood vessels

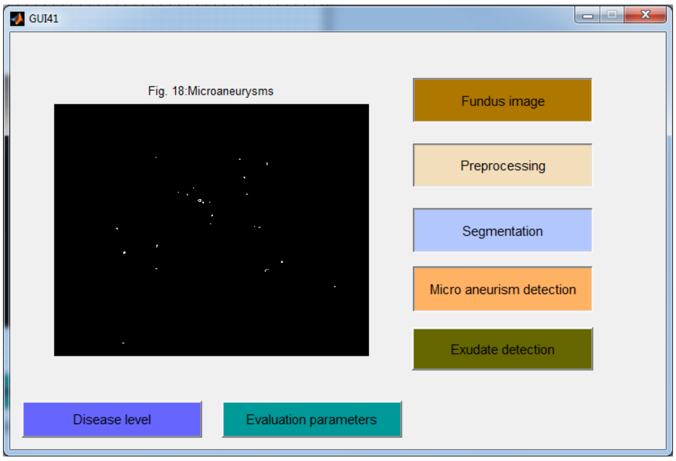

Fig.9. Detected micro aneurism

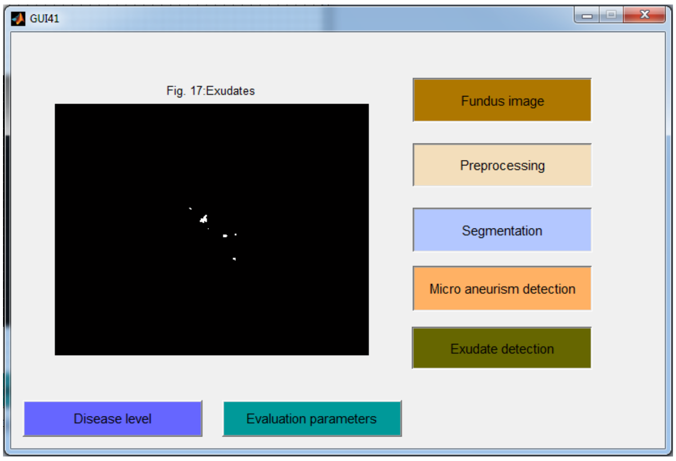

Fig.10. Detected exudates

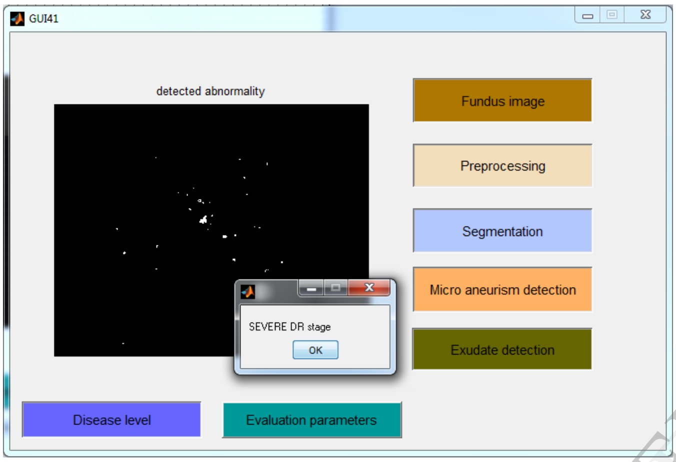

Fig.11. Disease level

V. Conclusions

Development of a system that will be able to identify patients with Normal, Mild and Severe from either color image or gray level fundus image. The different diabetic retinopathy diseases that are of interest include red spots and bleeding both falls between BDR and PDR stages of the disease. While SDR types are expected to be referred to the ophthalmologist Development of a MATLAB based Graphic User Interface (GUI) tool to be used by the ophthalmologist in marking fundus images. The marked images are to be used for the development of DR grading and database system for this present and future work.

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