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Automated Detection of Diabetic Retinopathy through Blood Vessel and Micro-aneurysms

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Abstract - Vision is the way we access, appreciate and interpret the world. Diabetic retinopathy is one of the common diseases which if remain undetected; causes blindness. Micro aneurysm is the first visible sign of Diabetic retinopathy; which appears like a tiny blood droplet on retinal fundus images. The bunches of Micro aneurysms may be examined to indicate the severity of the disease. The incidence of blindness caused by diabetes mellitus reduces by the early detection of MAs. This paper presents a novel approach for the automated detection of DR from fundus images using blood vessel perimeter measurement and Micro aneurysms count. The suggested method correctly identifies Micro aneurism even in poor quality image.

Keywords- *blood vessel; micro-aneurysms; fundus; hemorrhage*

I. INTRODUCTION

Diabetic retinopathy (DR) is a common complication of diabetes. Diabetes mellitus increases the amount of glucose circulating in the body consequently; the blood vessels present in the eye become progressively damaged [1]. As reported by the international diabetes federation, the number of adults with diabetes in the world is estimated to be 365 million in 2011. The number of people suffering from diabetes is increasing exponentially in India from 18 million in 1995 to expected 54 million in 2025. Currently diabetic retinopathy is the 3rd major cause of blindness in India [4].The early stage of DR is characterized by red lesions known as micro-aneurysms (MA) and bright spots such as hard and soft exudates in the eye. As the disease progresses further new blood vessels are created in retinal area [2].

. Diabetic retinopathy may be classified in various stages depending on the severity of the disease.

- The first detectable change to the retina due to DR is acknowledged as background retinopathy. The capillaries in retina become blocked, and start leaking blood. This is the least harmful stage as shown in fig1 (a).
- **Mild Non-proliferative Retinopathy**

This is the beginning phase of DR. It is characterized by the existence of dot and blot hemorrhages and MAs in the retina. This stage is depicted in fig1 (b)

Moderate Non-proliferative Retinopathy

This is the second stage of Diabetic Retinopathy. During this stage, some of the small blood vessels in the retina may actually become blocked, causing a decrease in the supply of nutrients and oxygen to certain area of the retina.

- **Severe Non-proliferative Retinopathy**

It is the stage when large number of small blood vessels in the retina gets blocked resulting in large region in retina being destitute of nutrition and oxygen.

- **Proliferative Retinopathy**

This is a stage of Retinopathy that bears the risk of eyesight loss. The retina acknowledges the shortage of oxygen. It attempts to compensate for the reduced circulation by developing new irregular blood vessels. This change is known as neovascularization. It is shown in fig1 (b) [3]

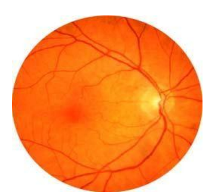

Figure 1 (a) Normal Image

Figure 1 (b) Non-proliferative diabetic Image

Figure 1 (c) Proliferative diabetic Image

The people affected with this disease may not experience any visual impairments or symptoms until it is progressed to advanced stage, when the treatment is less effective. Early diagnosis of DR through regular screening is the key to prevent visual loss. Diabetes afflicted population is very large in India and these patients need to be screened annually to allow for timely intervention and prevent the loss of vision. Automated DR screening system is expected to not only reduce the workload of ophthalmologists but also increase the level of accuracy.

A lot of work has been done in the area of DR detection using image processing techniques. In 2015 Jiri Minar proposed a method of automatic extraction of blood vessel and veins from fundus image using laplace operator [5]. N.S Dutta proposed a method where no remapping of the images histogram takes place only gray values are distributed in between two consecutive peaks which is called new contrast enhancement method of retinal images [6]. Manjiri B. Patwari, proposed a method of Automatic Detection of Retinal Venous Beading and Tortuosity by using Image processing Techniques [7]. Sandra Morales proposed computed aided diagnosis software for hypertensive risk determination through fundus images processing [8]. Tsuyoshi proposed a method of automated micro-aneurysm detection based on eigen value analysis using Hessian matrix in retinal fundus images [9]. Dr. Pradeep proposed a method of machine learning approach for the identification of diabetic retinopathy & its stages [10]. Akara Sopharak et.al , proposed a method in which Exudates can also be automatically detected by low-contrast digital images of retinopathy patients with non-dilated pupils by fuzzy c-mean clustering [11]. The proposed algorithm performs identification and detection of DR via combining results of the count of micro-aneurysms and permissible perimeter range of blood vessels and to achieve this green component of the fundus image is first segregated, then processes like opening and skeletization is employed to segregate blood vessels for perimeter evaluation and for estimating the count of MA's, MA is first segregated via edge detection algorithms then after removal of noise via median filter, roundness is checked to ensure that it is MA. The process employed makes the algorithm unique as it combines two approaches for detecting DR, as well as evaluation of roundness employed for MA's identification.

II. PROPOSED ALGORITHM FOR DR DETECTION

Figure 2 gives a generalized flow chart depicting algorithm proposed, employed in identification for various stages of DR. Algorithm combines abnormalities in the retinal blood vessels like change in perimeter and presence of micro-aneurysm and hemorrhages to be considered as a measure of severity of DR .

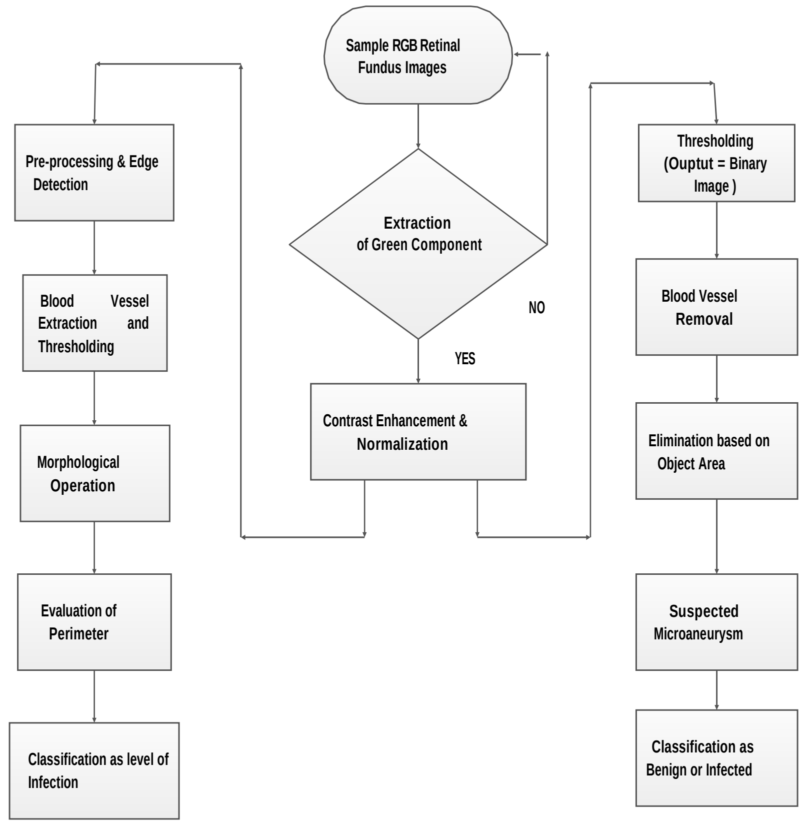

Figure 2: Flow chart for Diabetic Retinopathy Classification

Labeled fundus images were obtained from various genuine online databases (DIARETDB1) as well as local Laboratories. Primary task after obtaining labeled fundus images involved

i. Pre-Processing
ii. Detection of Abnormalities
iii. Feature Extraction
iv. Classification as benign or infected.

Algorithm proposed performs identification and detection via detection of perimeter of blood vessels and detection of micro-aneurysms.

III. PERIMETER ESTIMATION

Perimeter Estimation: Fundus image obtained is first converted in to gray scale after extraction of green plane. For shade correction (brightness and contrast correction), correction operator is applied. From the gray scale converted green plane image retinal blood vessels are extracted by edge detection. Thresholding is employed to obtain binary image. Segregation of blood vessels and elimination of isolated pixels is achieved via morphological opening. The resultant image clearly shows the outline of the vessels, from which the perimeter of the vessels can be estimated. Image mask is applied to eliminate the outline of the fundus, so that histogram of the output image gives the total number of pixels (bright pixels) corresponding to perimeter of the vessels [12]. Individual steps involved are:

i. Pre-processing

The color fundus image is encoded in memory as a Red, Green and Blue image depicted in figure 3(a). RGB images reserved color data using 8 bits specific for the RGB planes. During preprocessing the 8 bit green plane of the original fundus image is extracted. Intensity variations of blood vessels with reference to back ground are better identified in gray scale image than in colour image. So, the 8 bit colour image is transformed in an 8 bit gray scale image. This is done by edge detection. Canny edge detection algorithm (equation i) is used for edge detection , the algorithm uses Gaussian filter to remove noises and then does double thresholding to detect potential edges.

$$X = edge(Y, 'Canny' threshold) \ldots\ldots \text{i}$$

Where X is the processed image, Y is the ouput image and threshold is a vector with two identities having low and high threshold values. The result obtained gives image precedence to a group of joint curves which indicate the boundaries of objects, the boundaries of surface markings are curves which correlate to discontinuities in surface direction. Further to extract fine details of blood vessels, nonlinear Sobel filter is utilized, a high pass filter which extracts the curves of object. Nonlinear filters focuses on significant variations of the light intensity as well as, on the vertical and horizontal axes.

ii. Estimation of perimeter

Gray scale image is transformed into binary image using auto threshold depicted in figure 3(b), Segregation of blood vessels and elimination of isolated pixels is achieved via morphological opening given by equation (ii) and depicted in figure 3(c)

$$X \circ Y = (X \oplus Y) \oplus Y \ldots\ldots\ldots \text{ii}$$

Opening performs dilation followed erosion on the processed fundus image X, Y denotes structuring element utilized for performing Opening operation. Image obtained shows outer line of the vessels, from which the perimeter of the vessels can be easily evaluated. Depending upon image quality, few required processes like skeletization to further outline blood vessels to a finer level. The noise is further eliminated be the help of median filter.

$$Perimeter = \sum X_{EDGES} Y_{EDGES} W_{EDGES} Z_{EDGES} \ldots \text{iii}$$

Where XEDGES ,YEDGES, WEDGES and ZEDGES are top, left, bottom and Right corners of the edges of the perimeter being evaluated. Table 1 gives an approximate range of perimeter with reference to the type of diabetes identified and the same is depicted in figure 4.

Perimeter (Range in terms of Pixels)	Types of Diabetes suspected
285 – 400	No Diabetes
401-703	Non-proliferative Diabetes
402-1135	Proliferative Diabetes

Table 1: Type of Diabetes suspected with reference to Perimeter

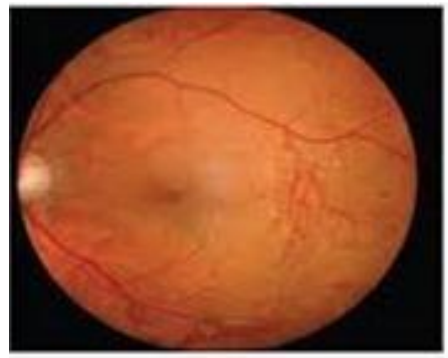

Figure 3 (a) input image

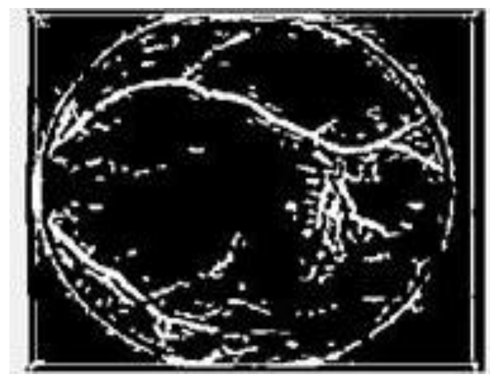

Figure 3 (b) binary image

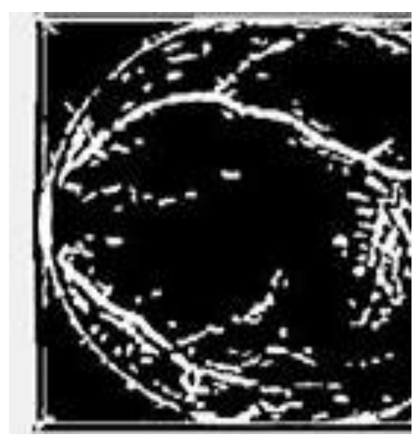

Figure 3 (c) Image obtained after morphological Opening

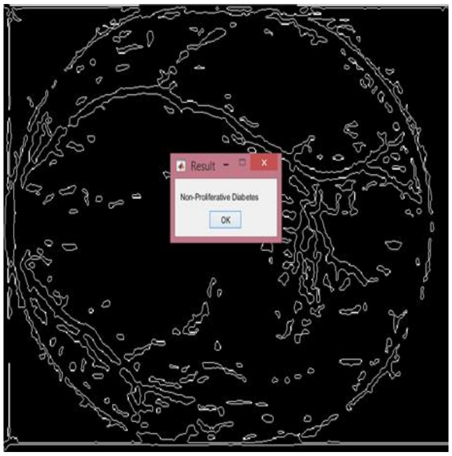

Figure 4: Classification of Diabetic Retinopathy

IV. MICRO-ANERYSMS EXTRACTION

Micro-aneurysms (MA) Extraction**:** Aneurysms are areas indicating swelling in blood vessels, representing hemorrhage in the retina, shown in figure 5. As in previous method first task involves pre-processing, it is done to reduce noise and enhance the contrast.

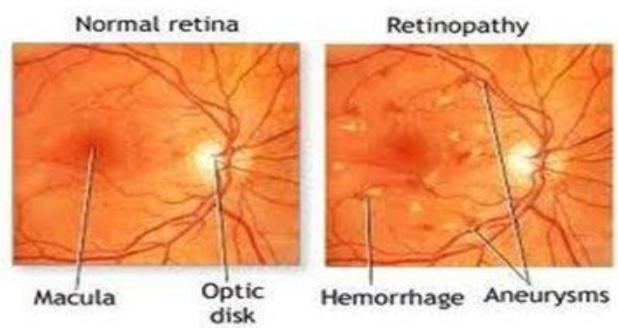

Figure 5: Hemorrhage and Aneurysms in retina

In RGB image, red and blue bear lot of noise whereas green channel has finest contrast between background and vessel. Hence preference is given to the green channel for further processing, shown in figure 6(a), the image obtained is converted to gray scale image, depicted in figure 6(b), in gray scale image, the retinal blood vessel bear a darker contrast as compared from rest of the image. Some of the feature like mass and blood vessels become invisible in the background after gray scale conversion. Visible level identification between background and features is achieved via contrast enhancement and normalization, depicted figure 6(c). For the normalization 20*20 median filter is used and for contrast enhancement adaptive histogram equalization, depicted in figure 6(d). After contrast enhancement, a dull area along with vessels micro-aneurysms and noise are predominant, shown in figure 6(e). The final stage in the pre- processing step is binarization. The binarization process is done by multilevel thresholding. After binarization the output image is ready for feature extraction, depicted in figure 6(f).

Feature extraction involves identification and extraction of Micro-aneurysms for diabetic retinopathy classification. MAs look as tiny red droplet of 10 to 100 micron diameter dark reddish in color and are circular in shape. After preprocessing the MAs are segmented by separating them from the blood vessel. Blood vessel and MAs, two look alike and MA's appear almost in same color on blood vessels. The MAs are detected on the basis of area because blood vessels are large in area as compared to MA's. To eliminate the blood vessels, objects that have area larger than threshold value are excluded, shown in figure 6(g). The resultant image mostly consists of MA's and noise, again micro-aneurysms detected from noise on basis of area. Two threshold values are fixed by experimentation to eliminate area greater and lower the MAs, the output image so obtained have particle that have same area. Noise is usually irregular in shape, MAs are circulars in shape but the resultant image is elongated in shape, shown figure 6(h). Finally, MAs are segregated on the basis of perimeter and circularity. Canny edge detection algorithm is utilized to obtain output image, shown in figure 6(i) Roundness is a measure to identify whether the object is circular or not and hence MA's. The formula also excludes local irregularities. Roundness can be evaluated by dividing the area of a circle to the area of an object by using the convex perimeter given in equation (iv).

$$Roundness = \frac{4\ X\ \pi\ X\ area}{perimeter^2} \text{.........iv}$$

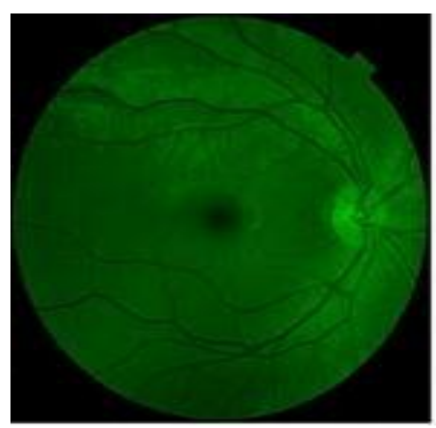

Figure 6. (a) Green Component of image

Figure 6. (b)Gray image of Green channel

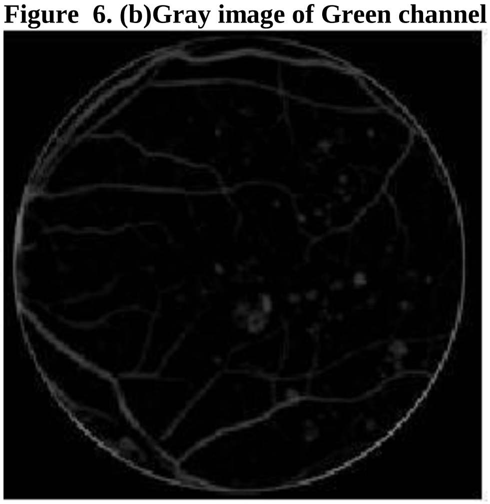

Figure 6 (c) Image obtained after median operation

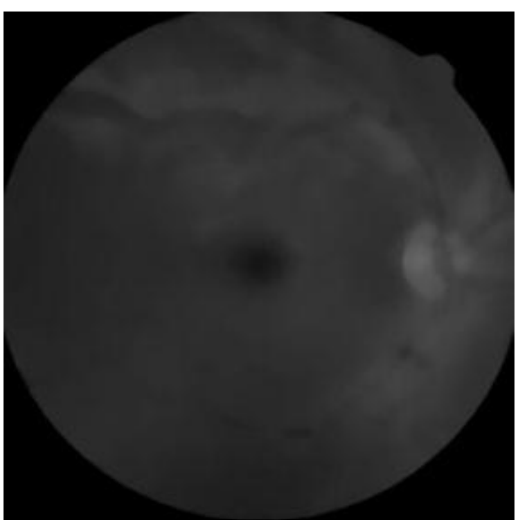

Figure 6 (d) Normalized image

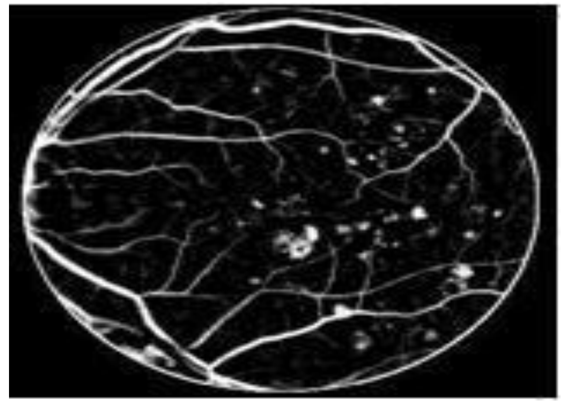

Figure 6. (e) Image after scaling

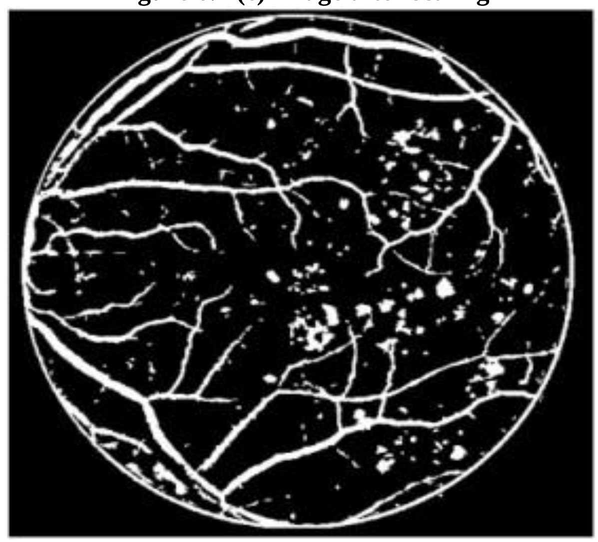

Figure 6 (f) Image obtained after thresholding

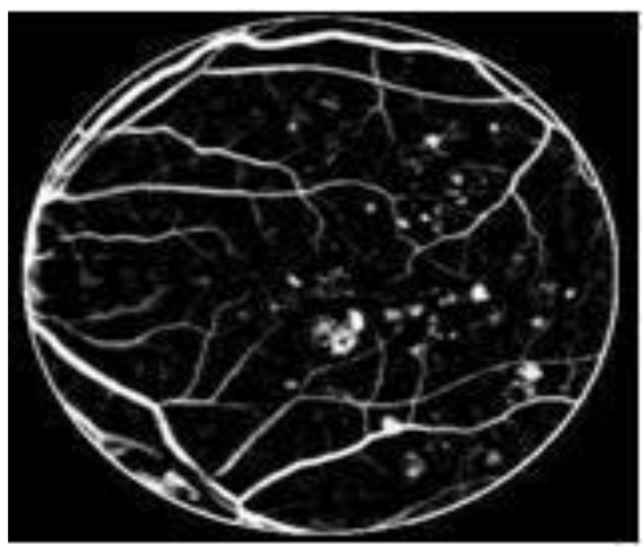

Figure 6. (e) Image after scaling

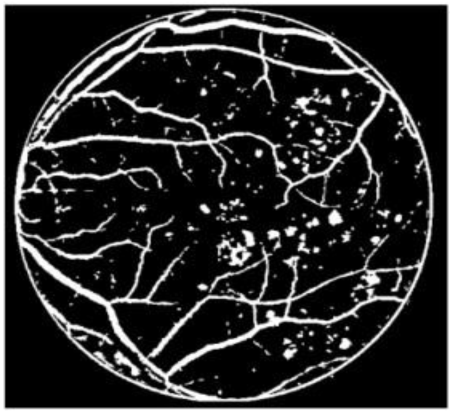

Figure 6 (f) Image obtained after thresholding

Figure 6. (g) Image obtained after removal of vessels

Figure 6. (h) Objects having similar area as Micro-aneurysms

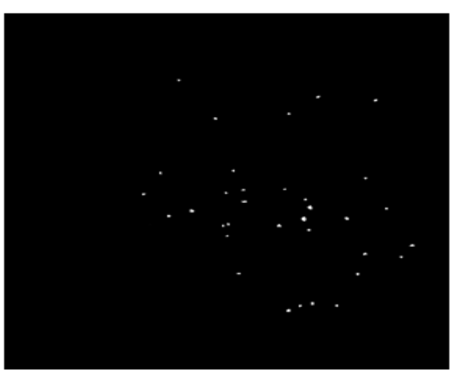

Figure 6 (i) Detected micro-aneurysms

Based on the count of MA's identified diabetic retinopathy can classified as benign , mild , moderate or severe stage, depicted in Table 2. The algorithm was evaluated on a sample of 90 images obtained from various genuine online databases (DIARETDB1) as well as local Laboratories; the accuracy achieved was 94%. The suggested approach was even able to correctly identify Micro-aneurism even in poor quality images owing to the procedure followed for preprocessing steps.

Table 2 Grading of Diabetic Retinopathy based on MA Count

Grade	MA Count	Interpretation
Grade 0	MA = 0	No DR
Grade 1	2<MA<6	Mild
Grade 2	6<MA<16	Moderate
Grade 3	MA>17	Severe

V. CONCLUSION

The proposed algorithm performs identification and detection of DR via combining results of the count of micro aneurysms and permissible perimeter range of blood vessels and to achieve this green component of the fundus image is first segregated, then processes like opening and skeletization is employed to segregate blood vessels for perimeter evaluation and for estimating the count of MA's, MA is first segregated via edge detection algorithms then after removal of noise via median filter, roundness is checked to ensure that it is MA. The process employed makes the algorithm unique as it combines two approaches for detecting DR, as well as evaluation of roundness employed for MA's identification. A new image processing technique for automated detection of diabetic retinopathy from non-dilated digital image of DR patients is proposed in this paper. The developed algorithm is applied to characterize the severity of DR and was evaluated on a sample of 90 images obtained from various genuine online databases (DIARETDB1) as well as local Laboratories, the accuracy achieved was 94% .

VI. REFERENCE

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