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Automatic Diagnosis of Diabetic Retinopathy Using Morphological Operations

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Abstract

Diabetic retinopathy is diabetic eye disease or a sight threatening complication (one of the major cause of blindness) for the person suffering from diabetes which causes progressive loss to the retina, in which retina of the eye is affected because the capillaries of the retina are damaged. Diabetic Retinopathy is unpredictable at early stage, it is only predictable in advanced stage when diabetic patient suffers from loss of vision due to leakage of lipid, blood vessels bursts and there is formation of new fragile blood vessels which blocks the blood supply to retina. Diabetic Retinopathy include Microaneurysm, hemorrhage and exudates. However, early detection and treatment is most important that can reduce the chances of occurrences of blindness about 95%. To analyze Microaneurysm and hemorrhage as early stages of DR is a challenging task for Ophthalmologists to prevent vision loss. Automatic analysis of Diabetic Retinopathy helps in preventing vision loss. Our proposed method is based on automatic detection of hemorrhage using colorful fundus images. In proposed work we have used supervised learning to classify the data as hemorrhage and without hemorrhage with SVM classifier. To find hemorrhage and its severity, we have extracted statistical features (including standard deviation, energy, entropy and contrast of an image), used classification approach and then segmentation methods. After feature detection, Morphological Operations are applied to detect blood vessels and hemorrhage detection with help of segmentation technique. Here the threshold optimization, Grey Wolf Optimization (GWO) techniques are used in our proposed work for getting maximum accuracy, sensitivity and specificity performance metrics.

Keywords: Hemorrhage dtetction; SVM classifier; Morphological Operations.

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1. Introduction

Chronically increased level of glucose in the patients with diabetes damage the tiny retinal blood vessels, which leads diabetic retinopathy. Most sensitive part of eye is retina that detects light which transform it into body signals and brain receive those signals through the optic nerve and we see the objects clearly. At early stages of Diabetic Retinopathy, patients are asymptomatic. Symptoms appears when disease become more severe. Diabetic Retinopathy has two main stages named as: non-proliferative retinopathy and proliferative retinopathy. In non-proliferative stage small red dots appears in the fundus image known as micro aneurysm which is leading cause of hemorrhage in which red spots appears and leakage of liquid occurs that cause poor vision. At mild non-proliferative stage blood vessel of retina that are carriers of oxygen and nutrients may swell and raptured. Proliferative retinopathy (PDR), most advanced condition of Diabetic Retinopathy, in which proliferation of new blood vessels occurs at the inner surface of retina due to secretion of growth factors and cause tissue damage and severe bleeding from retina. Detachment of retina can lead to permanent vision loss. DR conditions are described below in figure1.

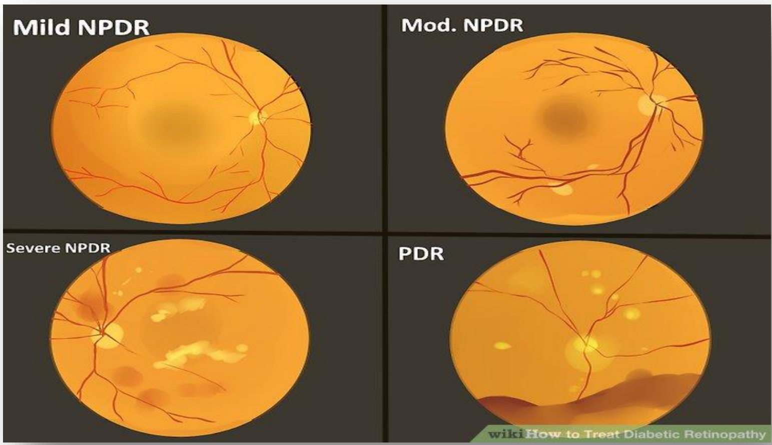


Figure 1: Stages of Diabetic Retinopathy

So the most important step for the patients with diabetes is regular eye examination and screening of diabetic eye disease that will need to obtain proper therapy before it may cause severe damage to eye and to measure its health conditions [1]. 75% of people with diabetic retinopathy survive in developing countries [2,3].

2. Related Work

It is important to diagnose Diabetic Retinopathy to controle the vision loss at early stages. Therefore, contributations has been made by different reseachers for the detection of Diabetic Retinopathy automatically such as; Shraddha Jalan and his colleagues described an algorithm KNN and SVM algorithm, Assistant professor (Sr.G) and his colleagues proposed method to diagnose DR, by using morphological operations and connected component analysis . It is also observed by extracting features from processed images that the images are exudates and non-exudates. All that work require more time and were energy consuming [1, 2, 4]. Vasanthi Satyananda and his colleagues Reviewed different methods to extract exudates from fundus images, the indicator of diabetic retinopathy. By using image processing techniques, author got highest possible accuracy based on histogram approach along with morphological operations, 90% accuracy is obtained [6]. M.A.Fkirin and his colleagues Proposed a new method for early diagnosis of Diabetic Retinopaty (DR), using rotating irregular filters. Different types of four filters are used for edge detection at different angles and can be applied individually. Here Laplacian of Gaussian filter is used that have highest sensitivity value and gave the best performance among the four used filters. STARE image database is used in this work [7]. Anupama Pattanashetty and his colleagues surveyed on various algorithms for detection of diabetic eye diseases like Exudes, hemorrhages, microaneurysms, and textures are utilized to recognize the phase of DR and concluded that there should be an advanced system i.e; a Computer Aided System to develop that will not only helpful for diagnosis of DR but also help in checking the progress of the disease so that its growth can be restricted if not prevented [8]. T. Ahmed, S. Junbin, G. Tariq, K and his colleagues provided a survey to analyze the fundus image through imaging techniques and pattern recognition approach. Author has analyzed most recent existing methods for detection of automatic DR (Pixel-to-Pixel methods), and segmentation of the retinal blood vessels and concluded that a fully automatic system of DR grading is needed for high accuracy to diagnose features of retinal image such as pathologies and retinal blood vessels [9]. K.Hari Babu and his colleagues formulated a new method and worked on analysis of the vasculature to measure the angiogram area surrounded by vessel and vessel length using FIS and Morphological operations. Author also had given difference that FIS and canny edge detector have no high accuracy but FIS and morphological operator are giving high accuracy and succeeded in blood vessel segmentation [10]. Nattanmai Balasubramanian Prakash and his colleagues Author described the proposed method to find the severity of Diabetic Retinopathy due to increased level of insulin through pre-processing , segmentation , feature extraction, Classification Phase I and Classification Phase II and to evaluate severity level he had used SVM classifier related to specific area and intensity of Exudates and Hemorrhages. For implementation of these methods STARE datasets and on real datasets through MATLAB 7.12, and get results in the form of sensitivity, specificity, and accuracy [11]. Saurabh Garg and his colleagues described automatic blood vessel segmentation based comparative study of supervised and unsupervised method using DRIVE dataset [12]. D Gowrishankar and his colleagues Diagnosed Diabetic Retinopathy by Automatic Extraction of Blood Vessels Exudates Segmentation using image thresholding, median filtering, morphological process [13]. ETIENNE DECENCIÈRE and his colleagues Explained the concept of evaluation of automatic lesion segmentation and diabetic retinopathy grading methods of eye fundus images through the Messidor database. Syamimi Mardiah Shaharum, Nurul Hajar Hashim and his colleagues Proposed automated computer vision method for detection of DR that depends on preprocessing, segmentation, feature extraction and then classification to determine the DR accurately in fundus image. In preprocessing impulse noise is removed by median filter, blood vessels's extraction is done using morphological methods,then feature extraction which is based on texture features including area of pixels, mean of pixels. After that classification is done using supervised learning through ANN and get results in the form of accuracy. For that they had used DRIVE Dataset [14]. Jitpakdee and his colleagues had described that Diabetic Retinopathy is a microvascular disease in loss of vision occurs due to deterioration of blood vessels and formation new fergile blood vessels. The earliest symptom of DR is hemorrhage, the severity of hemorrhage is specified through shape and number. Author also had given the information that automatic computerized systems for hemorrhage analysis have low efficiency because of algorithms and methodologies utilized were unable to distinguish hemorrhage from red blood vessels, fovea, other dark areas and even from Microaneurysm [15]. Acharya and his colleagues projected the hemorrhage, Microaneurysm and exudate detection using mathematical morphological processing techniques along with SVM classification approach and proposed the results in sensitivity and specificity as; 82%, 86% respectively [16]. Devaraj and his colleagues diagnosed Hemorrhage and Microaneurysm using morphological erosion and Adaptive Thresholding to enhance the contrast of an image to get better results on DIARTDB1 database [17].

3. Methodology

Proposed work is based on, to find normal and abnormal images and severity level of that abnormal image from fundus images. To analyze hemorrhage and its severity in region of fundus image, pre-processing, feature extraction, classification approach, Morphological methods and then segmentation techniques are utilized. The concept of research is described in below figure 2.

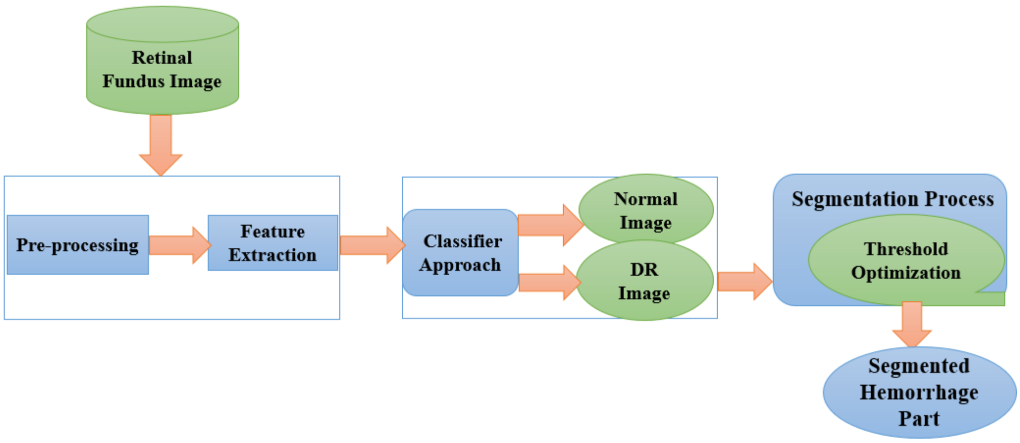
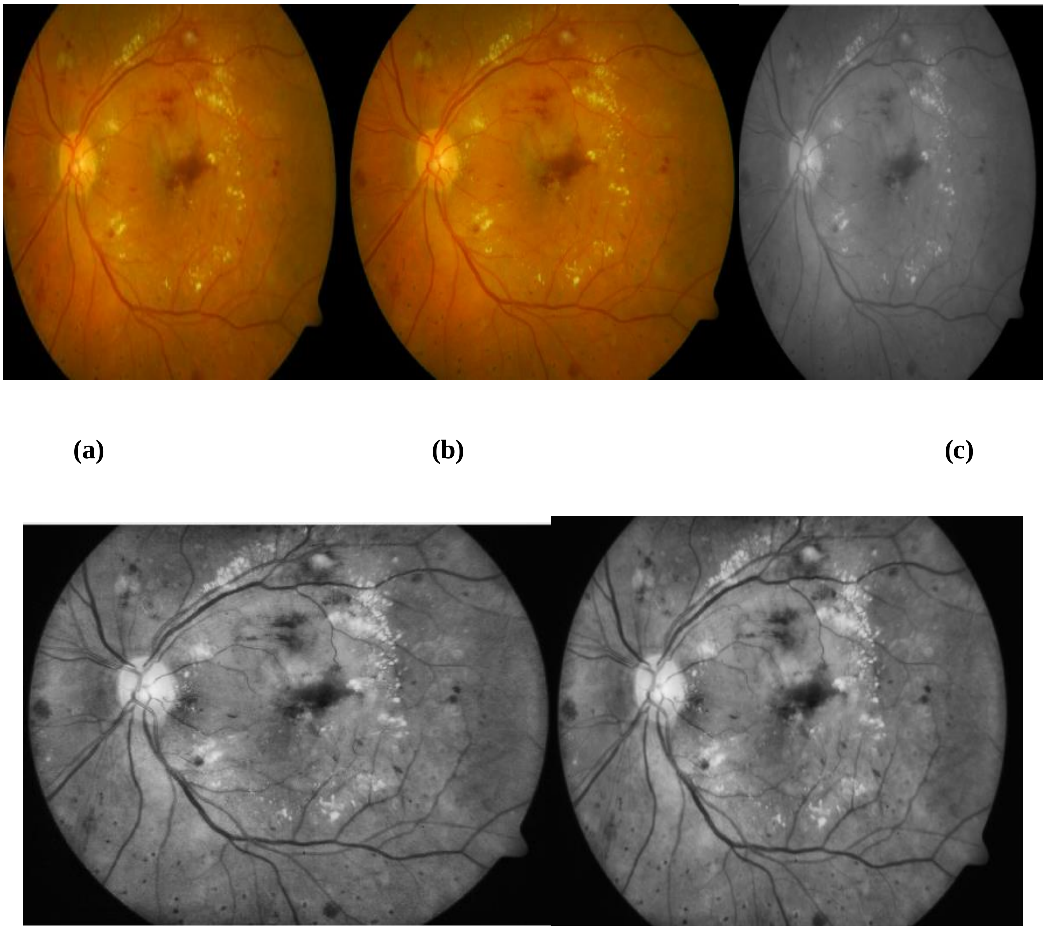


Figure 2: Steps of proposed method

3.1 Pre-Processing Phase

Preprocessing is based on filtration of fundus images of poor quality, convert colorful image into grayscale to extract blood vessels and hemorrhage part in an image. Median filter is used for elimination of unwanted noise and blur in the image without processing the edges of an image. Adoptive histogram equalization is also done for enhancement, to remove the noise and also used to improve contrast of an image. All fundus images are resized to 760 by 580 pixels for easy processing because all images are captured from different angles and from different cameras. These are clearly defined through figure 3 given below.



(a) (b) (c)

(d) (e)

Figure 3: (a) Original image, (b) shows resize of an image, (c) rgb to grayscale conversion, (d) Image after applying Adaptive Histogram Equalization, (e) shows filtered image using median filter

3.2 Feature Extraction

It is difficult to process the raw data, therefore; feature extraction is performed to get desired features from given fundus image. In our proposed method, we select statistical texture features to extract the retinal structure and hemorrhage detection. Statistical texture features measure indirect distribution of pixel values over neighbour values. The working principle is relying on first order, second order and high order pixel values. In first order we only compute one-pixel value without comparing it with neighbor pixel value. Whereas, in second order and high order we compute two or more pixel values and their co-occurrence in an image with same values. This is only possible through Gray Level Co-occurrence Matrix, in which we find similar values of pixels over neighbor pixel values and see the smoothness, contrast, uniformity of an image, energy entropy and variance of an image for the detection of hemorrhage. These are computed mathematically by equations as follows:

$$\sigma = \sqrt{\frac{\sum\left(\vec{I}(\mathrm{x},\, \mathrm{y}) - m\right)^2}{N}} \qquad (1)$$

Through energy (E), we measure the uniformity of an image and frequency of pixels with similar values. Pixels with similar values at every point in an image increases the energy and make an image smooth.

$$E = \sqrt{\sum_{i=0}^{N-1} \sum_{j=0}^{N-1} M^2 (i,j)} \quad (2)$$

Contrast most important step of image processing, measures the intensity of pixel and its neighbour in an image. Contrast is measured by finding the difference in brightness and color of an image within the same field of view.

$$Con = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} (i-j)^2 M(i,j) \quad (3)$$

3.3 Classification Approach

In proposed work SVM (Support Vector Machine) classifier that is subset of machine learning algorithm is used. SVM accuracy depends on training and testing of data. In training a model is build when new data is given and we predict the output in testing. There are two rules of SVM on which it classifies the data with high accuracy, according to first rule classify the two classes accurately whereas, in second rule SVM classify the two classes with maximum hyperplane distance that reduces the chances of misclassification. Here, are some mathematical description of algorithm as follows:

$$min_w \lambda \left|\left|w\right|\right|^2 + \sum_{i=1}^{n} (1 - y_i \langle xi, w \rangle) + \quad (4)$$

$$\frac{\partial}{\delta w_k} \lambda \|w\|^2 = 2\lambda w_k \quad (5)$$

$$\frac{\partial}{\delta w_k} (1 - yi \ \langle xi, w \rangle) + = \begin{cases} \text{o, if} & y_i \langle xi, w \rangle \geq 1 \\ -\text{yi xik, else} & \end{cases} \quad (6)$$

Where; xi is the input sample, yi is the output sample, w is the weight vector and λ is the regularization function.

3.4 Morphological Operations

Morphology is most advanced powerful tool which gives the detailed information about shapes and structure of an image shapes using mathematical operations in an image processing. In image processing it is used to extract meaningful information from images. In Morphological techniques erosion and dilation, opening and closing are performed. Through these operations we first detect the blood vessels then we remove them to see the hemorrhage clearly. In general, Morphological Operations are used for edge detection, feature extraction, noise elimination, image segmentation, and other image processing problems in Computer Vision and Image Processing [12,13]. Dilation and Erosion, two basic operators in Mathematical morphology. In Dilation objects seems to be lager by adding pixels near the boundaries and fills the inner gapes in that image. In Erosion objects will be smaller by removing pixels. Through these morphological techniques high intensity objects are localized and blood vessels are eliminated to see the Hemorrhage clearly. This can be done by closing operation which is also known as dilation and can be represented as:

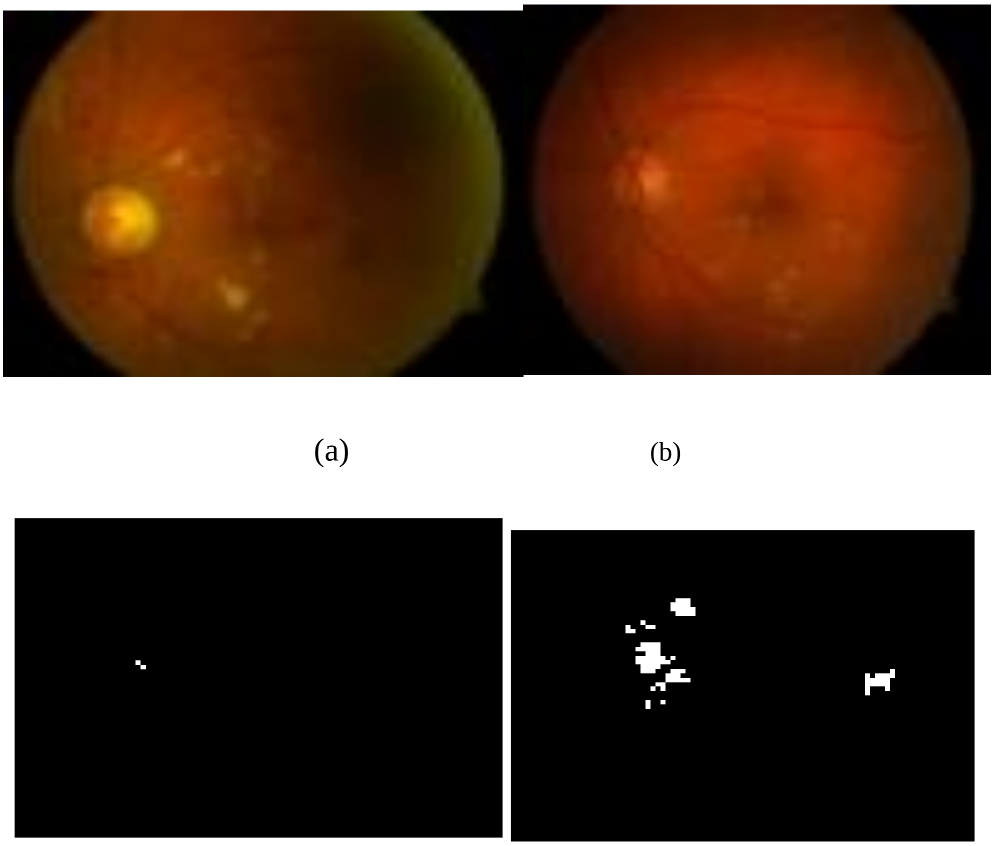
$$f \bullet B = (f \oplus B) \Theta B \quad (7)$$

Where f represent the original image, B is the structural element, $\oplus$ symbol for the grayscale dilation and Θ symbol for the grayscale erosion. In bottom-hat operation is done for extraction of blood vessels to analyze exudates accurately. But in proposed method through Top-hat operation blood vessels are eliminated and get maximum hemorrhage detection accuracy. Mathematical operation for Top-hat operation is given as:

$$\text{Top} - \text{Hat}\,(f) = f - (f \circ B) \quad (8)$$

$$f \circ B = (f \Theta B) \oplus B \quad (9)$$

Above mathematical expression is used for opening operation, whereas, $\circ$ is the grayscale morphological opening. In order to extract hemorrhage with high accuracy. Following results in figure 4 shows the detection of hemorrhage and removal of blood vessels through morphological operations



(a) (b)

(c) (d)

Figure 4: Hemorrhage detection using top-hat operation, removing blood vessels using top-bottom operation

3.5 Segmentation

Segmentation, most important part of image processing that involve in partitioning of images into segments to get meaningful information from that image. Here are some drawbacks in original image due to the intensity constraint that is scrutinized by the neighboring pixels. So shading in real images cannot be distinguished and there are chances of occurrences of noise in the intensity value. For better segmentation and to improve accuracy of segmented image, the optimal threshold value is predicted and Gray Wolf Optimization Techniques are utilized. Gray Wolf Optimization Techniques based on gridding, seed point selection, finding optimal threshold value, applying region growing to the seed point. [13] Gridding is the first step to implement the image in blocks (*bs)* that have resemblance with grid on image and assign each spot with individual parts. Next step is seed point selection in which histogram equalization is utilized for each pixel in the blocks, pixel value must be within 0 and 255 and most frequently repeated value is recognized as seed point.

$$Blocks\ (i,j)\ =\ fi\ (s:(s\ +bs)\ -1, p:(p\ +\ bs)\ -1 \qquad (10)$$

$$s\ =\ s\ +bs, p\ =\ p\ +bs \qquad (11)$$

whereas; for (i = 1…………….10)

(j = 1…………….10)

After selection of seed point, Gray wolf optimal thresholding techniques are applied to get segmented image with maximum optimal threshold value in the form of accuracy. This process is repeated until and unless high accuracy is obtained, as shown in figure;5 in the form of block diagram:

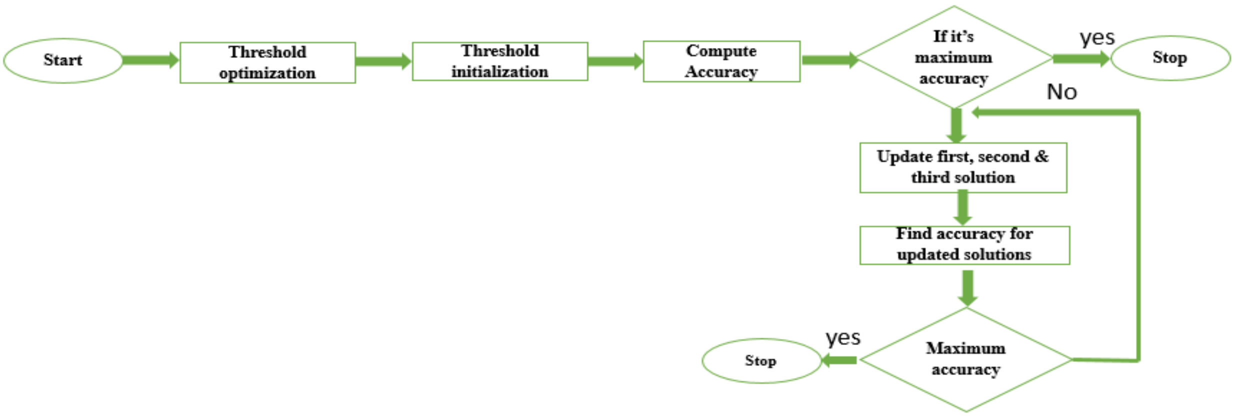


Figure 5: Block diagram for segmentation

Therefore, in each block maximum accuracy of segmented part can be find through parameters; True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN), by using formula as given below:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \qquad (12)$$

4. Database description

It is cleared from existing literature that most of work is done on DRIVE dataset and STARE dataset. Here, in this proposed work DIARETDB0, DIARETDB datasets, these images were taken in the Kuopio university hospital Finland and real dataset of 63 images from which 13 are normal fundus images and 50 are DR images, taken from Civil Hospital, and is used with high resolution and uncompressed format. From given data some images will be taken for training and some for testing purpose through mat lab tool. About 80% images are used for training and 20% images are used for testing purpose. Here, DIARETDB0 contains 130 images from which 110 are DR affected and 20 images are normal, whereas, DIARETDB1contains 89 fundus images from which 84 are DR affected and 5 are normal images. Therefore, total images in proposed method are 282, from which 41 images are taken for testing and 225 images are taken for training purpose. This process is repeated for several times to get average results in the form of sensitivity, specificity and accuracy.

5. Results and Discussions

Different datasets are employed in our research that consist of DIARTDB0, DIARTDB1 and real dataset which contains 63 total fundus images. SVM classifier approach is used as automatic detection of the diseased image and normal images then further segmentation is performed to see low level and high level hemorrhage with pixel to pixel variance in an image. SVM classifier is only applicable on smaller dataset about thousands not more than thousands, due to its limitation it is not applicable on big dataset. This is the limitation of this classifier which may also affects the accuracy to find any pathology. To find pixel to pixel similarity value using modified Gray Region Threshold Optimization in which we define that how pixel value is similar with its neighbour pixel value. If there is variance in pixel values with respect to its neighbour pixel value, then we estimate the severity of hemorrhage in that part. In this method Morphological operations are applied to detect Hemorrhage and remove the blood vessels because hemorrhages are adjacent to blood vessels. In last we summarized the results in the form of sensitivity, specificity and accuracy as 96.81%,89.77%, 92.65% respectively. In proposed method manifold testing and training is performed to get high accuracy, sensitivity and specificity shown below in graph in figure;6.

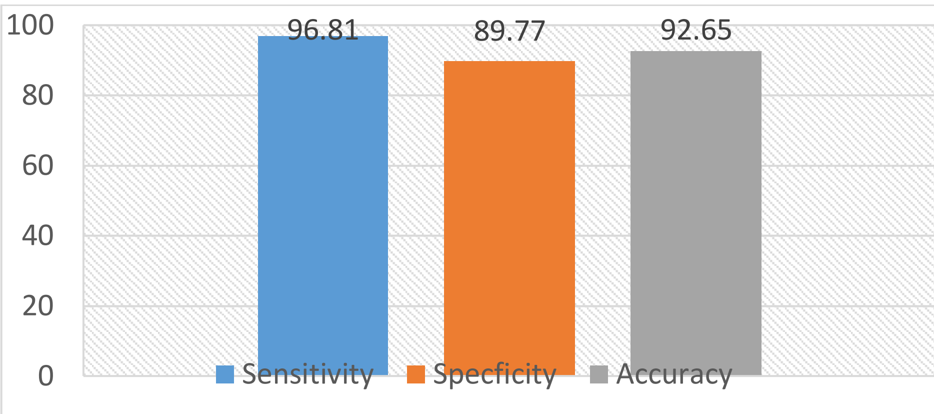


Figure 6: Graph shows the results in the form of sensitivity, specificity and accuracy

6. Conclusion

As Diabetic Retinopathy is sight threatening disease, patients with Diabetic Retinopathy become unable to do even any normal activity. So, it is necessary to diagnose this disease at early stage by recognizing its symptoms of DR to control the disease in efficient way if can-not be prevented. Here in my proposed work, I have used an effective automatic detection method for hemorrhage findings at its early stage. Automatic detection system relay on texture feature extraction to distinguish hemorrhage part and blood vessels easily, classification approach, and then segmentation approach to see the similar pixel values using Matlab 2016a. We can enhance the efficiency of the system by using more advanced methods to get high accuracy in finding those pathologies which are difficult to diagnose manually.

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