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Diabetic Retinopathy Detection Using Voting Classification Method

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Abstract

The image processing approach is deployed to process the information available in the pixels of images. The medical images processing method is extensively exploited to detect distinct types of diseases. The retinal disease may occur in the diabetic patients that leads to create specific spots around the eyes of an infected individual. This disorder is called diabetic retinopathy. The image processing-based technique (IPT) are effective to diagnose such a disease in 2 stages. First of all, the features are extracted and the disease is classified later on. The present work suggests a voting classification technique which is the combination of SVM, KNN and random forest for the diabetic retinopathy detection. The suggested method is tested concerning accuracy, precision and recall.

Keywords: Diabetic Retinopathy, Feature Extraction, Classification, Segmentation

1. Introduction

1.1 Diabetic Retinopathy

Diabetic retinopathy (DR) is one of the main causes of impaired vision worldwide. During the preliminary period of this disorder, numerous irregularities are occurred in the fundus of the eye due to which the microvasculature of the retina are infected. MAs, exudates, etc. are some of these irregularities. Diabetic retinopathy lesions are rapidly changes and retinopathy is taken place in a gradual wat at its primary phases. Early detection and treatment of diabetic retinopathy (DR) play a crucial role due to its progressive nature and the impact of lesion numbers and types on its severity, as depicted in fundus imagery. DR is categorized into two main levels: proliferative diabetic retinopathy and NP-diabetic retinopathy [1]. The latter one is called a background DR, occurring in case, diabetes weakens the blood vessels in the retina, leading to blood leakage and fluid accumulation on the retina's surface. This leakage impairs the retina's sensitivity as it becomes swollen and moist. The implementation of computerized detection techniques for diabetic retinopathy holds the potential to save significant time and effort. Furthermore, various image processing methods are developed to aid in the detection of diabetic retinopathy.

1.1.1 Diabetic Retinopathy Detection Process

To facilitate Diabetic retinopathy screening, a CAD method has been constructed to distinguish between retinas with potential diabetic retinopathy (DR) and normal retinas. The process to detect this disease, typically involves diverse phases: Figure 1 depicts a general process of DR (Diabetic Retinopathy) detection.

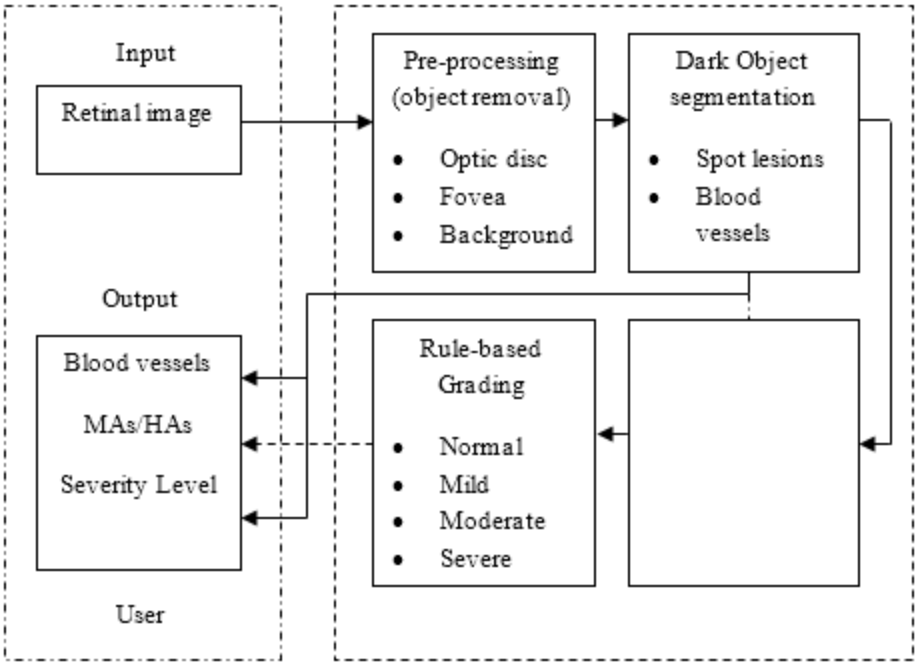

Figure 1: Diabetic Retinopathy Detection Process

Distinct phases executed to detect DR disease are explained as:

a. Input image: The input image in DR screening is a colored picture of the human retina, usually taken with a fundus camera. The resulting output is considered as a binary picture that indicates presence of spot lesions and the seriousness of DR disorder [2].

b. Pre-processing: The pre-processing stage plays a vital role in preparing retinal fundus images for segmentation. In certain instances, image capture occurs under complex conditions, resulting in non-uniformly illuminated, noisy, or low-contrast pictures. These kinds of pictures can significantly impact the effectiveness of the segmentation algorithm. Therefore, this process employs various approaches which pre-process the data to address these issues. Commonly used techniques include extracting the green channel, eliminating OD, and normalizing the background of the image.

- Green-channel extraction: This method focuses on splitting the colored test images into 2 sets according to their size. The green channel is then utilized to maximize the local contrast between the pixel values and the color image components. Initially, it aims to extract the green channel (IG) from colored image. This is done because of the distinctive characteristics of microaneurysms and hemorrhages, which can be better observed in the green channel.
- Optic disc removal: During this stage, specific retinal features like OD and fovea are eliminated from the retinal pictures. The optic disc (OD) possesses distinct characteristics that indicate its precise location within the image. It is worth noting that dark objects may sometimes be present within the optic disc [3]. These objects can be recognized as microaneurysms or hemorrhages. Thus, removing the optic disc is crucial for eliminating these potentially unclear substances. The OD is typically positioned in the middle third of the image because of location of the image capturing tool.

Therefore, methods of removing OD primarily focus on this middle third of IG image (f_G) as ROI. Subsequently, a filtering technique helps in processing the retinal picture. The median filter is a commonly utilized technique in pre-processing the images.

- Background removal: The main purpose is of removing background inconsistencies in illumination from an image. This approach is utilized for simplifying the analytic procedure of foreground objects. The primary task is of enhancing the contrast of the image to attain an optimized image so the upcoming image is further analyzed. Diverse factors lay impact on the image contrast. Thus, a number of techniques are put forward to enhance the contrast of captured pictures.

c. Dark spot segmentation: The dark spot lesions are segmented in dissimilar stages. These stages involve three operations which are discussed as follow:

- h-Maxima transformation: In this stage, this method is applied to the pre-processed images. The chief objective of alleviating the amount of brightness levels in images. If 'I' represents an intensity picture, this approach is adopted to suppress all the local maxima in 'I'. The resulting image will contain values that are lower than a specified threshold 'h'. This can be expressed as:

$$\mathrm{H}_h(\mathrm{I}) = R_I^{\delta}(I - h)$$

In this, R_I^{δ} is employed to illustrate the morphological reform based on dilating an image I. Particularly, the quality level is found different in all the pictures. The quality of an image is decided according to the circumstance of capturing that picture [4].

- Thresholding: A thresholding method is employed on the intensity image Hh to segment microaneurysms and hemorrhages. The primary objective of this method is to generate a binary image where each pixel is assigned a specific value based on a threshold. However, the traditional techniques are ineffective of generating optimal outcomes for each image. Thus, a multilevel thresholding technique is put forward on the images prior to transform them into black& white. This technique is adopted for simplifying the procedure of selecting threshold value. It results in mitigating in the number of intensity levels for converting a gray-scale image into an indexed image.
- Feature extraction: As a result of the earlier process, false positives such as blood vessels and irrelevant pixels may appear in the resulting binary image. To address this issue, the post-processing methods are adopted to refine the image and retain only the relevant objects. Typically, these objects include microaneurysms (MAs) and hemorrhages (HAs).

d. Dark spot classification: The A variety of spot lesions can be classified using crucial parameters. Hard exudates, MAs, and Has, etc. are the names given to these spot lesions. Many different categorization methods have been provided by various academics in attempt to classify the disease according to the level of risk. The SVM, K-NN, DT, NB, and other widely used classification methods are some examples. [5]

e. Severity level grading: This stage is executed for classifying the risk factor of DR into 4 classes. An increase is found in this level after the maximization of scale. The initial one is called “normal” or “no apparent retinopathy”. It is employed for defining the regularity of the eye retina. The second one is called “mild NPDR”. At the final stage, the retina of the eye only has MAs (Micro aneurysms). The next one is “moderate NPDR,” which is labelled to show the extensive

progress in the severity level. The final one known as "severe NPDR" is the most hazardous level of DR disease.

1.1.2 Classification algorithms

After extracting the significant attributes from the retina image, a classifier is adopted on the extracted attributes for categorizing the disease according to its risk level. These methods deploy the evaluated values of all extricated attributes. Some extensive classifiers are explained as:

a. Support Vector Machines: This approach is adopted for classifying the data into diverse classes. Support Vector Machine model is capable of handling a variety of constant and unconditional variables accurately. A hyperplane is acquired from this method in the multi-dimensional space with the objective of separating all categories from one another. Consequently, the errors are mitigated with this hyperplane. The concept to investigate the MH is considered in this approach. This hyperplane is exploited for segregating the dataset into diverse sections. It uses the support vectors for defining the data points available nearer to the hyperplane, which are capable of evaluating the margins. It leads to define the separating line in an effective manner. These data points are required in generating this algorithm [6].

b. K Nearest Neighbor Classifier: K-Nearest Neighbors is a widely utilized algorithm in the arena of ML. It is frequently employed to accomplish various purposes such as to detect an object, data mining, and pattern recognition. One notable aspect of this algorithm is that it does not make any assumptions about data allocation and instead utilizes existing data to classify coordinates into groups based on their features. KNN approach assists in quantifying the distance among data points. This distance is called ED. The given expression is executed to compute the distance among data points as:

$$d(p,q) = d(q,p) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \cdots + (q_n - p_n)^2}$$

$$= \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2} ----(1)$$

Here, the dimensions or features are represented with n in ML. It is assumed that the location of data point is at slight distance from the testing point available in the similar class which a test point contained. The given expression is used for this objective in 'n' dimensions. Thus, it is an appropriate formula in case of n number of features.

c. Decision tree: It is a significant method to perform categorization and prediction. It involves conducting tests on features at internal nodes and assigning class labels to leaf nodes. Through repeated partitioning and testing of subsets, this approach can handle large amounts of data and consistently provide accurate results. Notably, the generation of this classifier does not require any specific domain knowledge or parameter configuration. This particular classifier has the capability to effectively manage a vast amount of data and usually yields highly precise results.

2. Literature Review

Yash S. Boral, et.al (2021) recommended an approach to diagnose DR on the basis of an improved method for boosting the accuracy [7]. ATL method was put forward for customizing several functions of Inception V3 which was useful in classifying the image. SVM approach was effective for classifying the pictures as Diabetic Retinopathy positive and normal. According to simulation results, the recommended approach was applicable in detecting Diabetic Retinopathy at superior accuracy. A less expensive CAS mechanism was presented by Md. Mahmudul Hasan Sabbir, et.al (2020) in order to detect DR from color fundus pictures [8]. An EL algorithm was suggested to maximize the accuracy of system along with a number of ML algorithms. Besides, Gray Level Co-occurrence Matrix was exploited for extricating the texture features which were further

deployed to train the utilized techniques. These attributes were considered to evaluate the patterns from any images. The MESSIDOR database was executed for computing the suggested algorithm. The experimentation indicated that the voting-based EL method worked efficiently with sensitivity up to 97.2%, specificity up to 78.6% and accuracy around 92.0% against the traditional methods. A DL-based method was introduced by Narjes Karami, et.al (2017) with the objective of diagnosing the Diabetic Retinopathy automatically in digital fundus images [9]. The learned dictionaries of K-singular value decomposition model had considered according to the atomic depiction of fundus pictures. These dictionaries were employed to differentiate the healthy pictures from the infected ones. Based on experimentation, the presented approach had effectively diagnosed Diabetic Retinopathy with accuracy of 70.01% to detect normal images and 90% for infected ones. A novel and hybrid method was developed by Anas Bilal, et.al (2021) for detecting and classifying Diabetic Retinopathy [10]. This method had incorporated various mechanisms to make the process, used to detect Diabetic Retinopathy, more robust after categorizing it. The majority voting technique was deployed to classify disease. The major emphasis was on pre-processing the image and improving the availability of abnormality. The attributes were extracted precisely and 3 algorithms, called, Support Vector Machine, K-Nearest Neighbor and Bayesian method were presented for classifying the pictures. In the experiments, the developed method offered 0.9806 accuracy, 0.8367 sensitivity and 0.100 specificity. Elaouaber Zineb Aziza, et.al (2019) aimed to formulate an automated mechanism for diagnosing Diabetic Retinopathy from RGB pictures [11]. The blood vessels were segmented in this approach and the geometric features were extricated to detect Diabetic Retinopathy in advance. The Hessian matrix, ISODATA algorithm and active contour methods were created to segment the blood vessels. The last task to develop Decision Tree-CART algorithm to categorize the images into healthy and infected with Diabetic Retinopathy disease. The results generated on DRIVE and Messidor data sets, validated that the formulated mechanism was feasible to diagnose DR accurately as compared to the outdated methods. A CAD method was constructed by Arwa Gamal Eldin, et.al (2020) for dealing with drawbacks of SVM model for categorizing the images [12]. This method made the deployment of NN for diagnosing DR from fundus pictures. The techniques of segmenting images were exploited so that the fundus images were processed to detect the diverse features, such as blood vessel region, MA and texture. The constructed method was simulated on IDRiD database in which around five hundred sixteen images were contained. This method was capable of classifying the images into 3 categories, namely: normal, Diabetic Retinopathy infected and micro-aneurysms. The results revealed that the constructed method yielded an accuracy of 96%, sensitivity of 98% and specificity of 67%. An innovative and automatic method was presented by Pan Junjun, et.al (2018) for diagnosing Diabetic Retinopathy with DCNN [13]. An attention technique was adopted to identify ROIs with the objective of allocating score to certain section known as RSM. This technique was useful to score diverse portions of retina image for which diverse regions of interest were highlighted relied on severity level of image. Around five thousand images were employed to compute the presented technique in experimentation. Based on findings, the supremacy of the presented technique was proved against the classic schemes at enhanced RSM to locate the discriminative areas of the input image. A new automatic HPTI-v4 method was projected by K. Shankar, et.al (2020) that diagnosed and categorized Diabetic Retinopathy from color fundus pictures [14]. The CLAHE method was implemented to pre-process the images with the purpose of enhancing the contrast level of the picture. Furthermore, this method was assisted in extracting features from the segmented images. The images were classified using MLP model on the basis of extricated features. The projected method was quantified on MESSIDOR dataset against the existing methods. The experimental outcomes depicted the superiority of the projected method over others for detecting DR. A novel method was put forward by Tahira Nazir,

et.al (2020) in which Faster RCNN was deployed to overcome the issues about methods of detecting DR lesions and to diagnose the early symptoms in an exact way [15]. The initial task was of pre-processing the images and locating the irregularities of Diabetic Retinopathy as MA and HAs etc. the simulation was carried out on Diaretdbl and Messidor data sets. The simulation results validated that the accuracy of presented method was calculated 95% and IOU was 94%. Furthermore, this method outperformed the traditional techniques. Enrique V. Carrera, et.al (2017) focused on CAD framework in which digital retinal images were pre-processed for detecting diabetic retinopathy in advance [16]. This framework was employed to classify grade of Non-Proliferative Diabetic Retinopathy in an automatic way. The microaneurysms and hard exudates were isolated to extricate the features at initial stage when the image was processed. These features were inserted in Support Vector Machine to detect retinopathy grade of each retinal picture. This framework labeled four hundred images based on 4-grade scale of Non-Proliferative Diabetic Retinopathy which were contained in a dataset. The presented framework was evaluated on this dataset. The experiments depicted that the presented framework offered a sensitivity around 95% and potential to predict the disease up to 94%. An automatic technique was intended by C. Jayakumari, et.al (2020) to diagnose and classify the DR depending upon the ImageNet model for attaining superior accuracy [17]. The Kaggle dataset was applied to simulate and analyze the performance of the intended technique. This Comparison Table technique was proved adaptable for diagnosing and categorizing the images in effective way. The accuracy of the intended technique was counted 98.6% when the data was trained. The amount of pictures was enlarged for training this technique so that the accuracy was augmented. An Automatic Mechanism was designed by Navoneel Chakrabarty, et.al (2019) to distinguish the diseased eyes from healthy ones in accordance with HR pictures [18]. Various methods, namely Greyscale Conversion, Thresholding and Binarization were exploited to process the pictures. A hybrid of FF-CNN-SVM was presented and adopted for classifying these images into Diabetic Retinopathy and normal. The experiments demonstrated the supremacy of the designed mechanism with accuracy of 100% to diagnose disease. Dinial Utami Nurul Qomariah, et.al (2019) analyzed that the fundamental objective was to prevent the severity of DR when this disease was detected at initial stages [19]. A DL method was projected for extracting the features and categorizing the illness with the help of SVM. The features of higher level of final FCL were extracted using Convolutional neural network model. The TL method was exploited and Support Vector Machine algorithm deployed these extricated features for classifying the images. The used model was effective to decrease the computational time. The projected method was quantified on Messidor database with base 12 and base 13. According to experiments, the projected method provided an accuracy of 0.9583 for initial base and 0.9524 on latter one.

Author/Year	Technique Used	Dataset	Advantages	Disadvantages
Yash S. Boral, et.al. 2021	An improved method	Kaggle database	According to simulation results, the recommended approach was applicable in detecting Diabetic Retinopathy at superior accuracy.	The unstable image laid a negative impact on the efficacy of this approach.

Md. Mahmudul Hasan Sabbir, et.al. 2020	A CE-CAS System	MESSIDOR dataset	The experimentation indicated that the suggested method worked efficiently with sensitivity up to 97.2%, specificity up to 78.6% and accuracy around 92.0% against the traditional methods.	This method was not adaptable for soft majority voting application.
Narjes Karami, et.al. (2017)	DL-based technique	Kaggle database	Based on experimentation, the presented approach had effectively diagnosed Diabetic Retinopathy with accuracy of 70.01% to detect normal images and 90% for infected ones.	This approach was unable for categorizing the pictures into dissimilar classes.
Anas Bilal, et.al. 2021	A novel and hybrid method	Indian diabetic retinopathy image dataset	In the experiments, the developed method offered 0.9806 accuracy, 0.8367 sensitivity and 0.100 specificity.	This method was not performed well in the presence of complicated data.
Elaouaber Zineb Aziza, et.al. 2019	An automated mechanism	DRIVE and Messidor	The results generated on DRIVE and Messidor data sets, validated that the formulated mechanism was feasible to diagnose DR accurately as compared to the outdated methods.	This mechanism had not screened the disorders based on other components: MAs and hemorrhages.
Arwa Gamal Eldin, et.al. 2020	A CAD method	Indian diabetic retinopathy image dataset	The results revealed that the constructed method yielded an accuracy of 96%,	The constructed method had generated least recall.

			sensitivity of 98% and specificity of 67%.	
Pan Junjun, et.al. 2018	DCNN	EyePACS	Based on findings, the supremacy of the presented technique was proved against the classic schemes at enhanced RSM to locate the discriminative areas of the input image.	The issue of class imbalance was occurred.
K. Shankar, et.al. 2020	A new automatic HPTI-v4 method	MESSIDOR data set	The experimental outcomes depicted the superiority of the projected method over others for detecting DR.	This method was unsuitable in the application of classifiers.
Tahira Nazir, et.al (2020)	Faster RCNN	Diaretdbl and Messidor data sets	The simulation results validated that the accuracy of presented method was calculated 95% and IOU was 94%.	This method had not diagnosed other retinal image disorders like Cataract, etc.
Enrique V. Carrera, et.al. 2017	Computer Aided Diagnosis system	Messidor database	The experiments depicted that the presented framework offered a sensitivity around 95% and potential to predict the disease up to 94%.	This framework was not robust for detecting all kind of abnormalities.
C. Jayakumari, et.al. 2020	An automated technique	Kaggle	The accuracy of the intended technique was counted 98.6% when the data was trained.	The intended technique offered poor recall in case of enormous amount of images.
Navoneel Chakrabarty, et.al. 2019	A hybrid of FF-CNN-SVM	HRF dataset	The experiments demonstrated the supremacy of the designed mechanism with accuracy of 100% to diagnose disease.	This mechanism was not effective for enormous datasets.

Dinial Utami Nurul Qomariah, et.al. 2019	DL method	Messidor data set	According to experiments, the projected method provided an accuracy of 0.9583 for initial base and 0.9524 on latter one.	This method was not applicable on large sized data and classes.

Research Methodology

This research work focuses on detecting DR. DR is detected in several stages in which the images are pre-processed, segmented, features are extracted and DR is classified. The steps for the diabetic retinopathy detection are explained below: -

1. Input Image and pre-processing: -First of all, a retina image is acquired as input. Then, this image undergoes pre-processing stage where this image is made denoised by different filters.

2. Segmentation: -Segmentation is performed by applying CHT (Circular Hog Transformation) method on the pre-processed image. This method after segmenting blood vassals removes redundant image portion. Optic Disc represents a bright yellowish or white region. This region remains present within the colored fundus pictures. OD has intensity similar to exudates. Hence, it is highly important to remove OD from retinal image. Masking and removal of this part is carried out by means of area attributes and region detection. Once the pre-processing is over, OD and blood vessels are figured out with edge detection algorithmic approach. This work applies canny edge detection technique to find out counters. This technique preserves every local maximum termed as gradient. This process is important for make the blurry edges clear. In fact, this is the best way for detecting attributes' edges. The mask picture is created by generating the logical B&W function and the image inversion.

3. Feature extraction: - GLCM algorithm is applied in this stage for texture feature analysis. This algorithm measures thirteen attributes for making the recognition of DR disorder possible. Both blood vessels and optical disc have similar concentration levels. Dilation is implemented on the image illumination for retrieving blood vessels with more contrast levels. In addition to this, the application of dilation and structuring element fill tiny holes in pictures. There may be various shapes of Structure elements (SE). The Flat disc configuration is extensively utilized method to eliminate the blood vessels and OD.

4. Classification: -At the end, classification is performed by implementing a hybrid approach. The approach will create a training set with 13 attributes for classifying diabetic images into diseased and healthy. The hybrid approach of SVM, KNN and RF. The K nearest neighbour is the multi class classifier. This classifier classify data on the basis of similarity function. The similarity function is calculated through the Euclidian distance. In the KNN classifier training set is prepared and test set is compared with the training set to find predicted result. The training set is compared with the test set through the similarity function which works on the basis of Euclidian distance. The KNN classifier is best suited to classify the data. Random Forest algorithm is simple yet flexible machine learning algorithm. The random forest algorithms works based on the tree predictions its means that this algorithm will derive tree structure of the input data to produce final predicted result[20-25]. Random forest algorithm is accepted for classification as well as for regression. This algorithm is consisted of hyper parameters similar

to a Decision tree classification. The overlapped RT in this algorithm is the base of the Random Forest algorithm and can be checked effortlessly. For example, 7 RTs are assisted in providing information about some variables and 4 among these trees agree and the rest are not. ML models are built based on majority voting. In Random Forest, results at higher accuracy are achieved from a random features subset in the dataset. The output of both RF and K-Nearest Neighbor is fed as input to the voting classifier for voting amid two algorithms and creating the final predictive outcome[26-39].

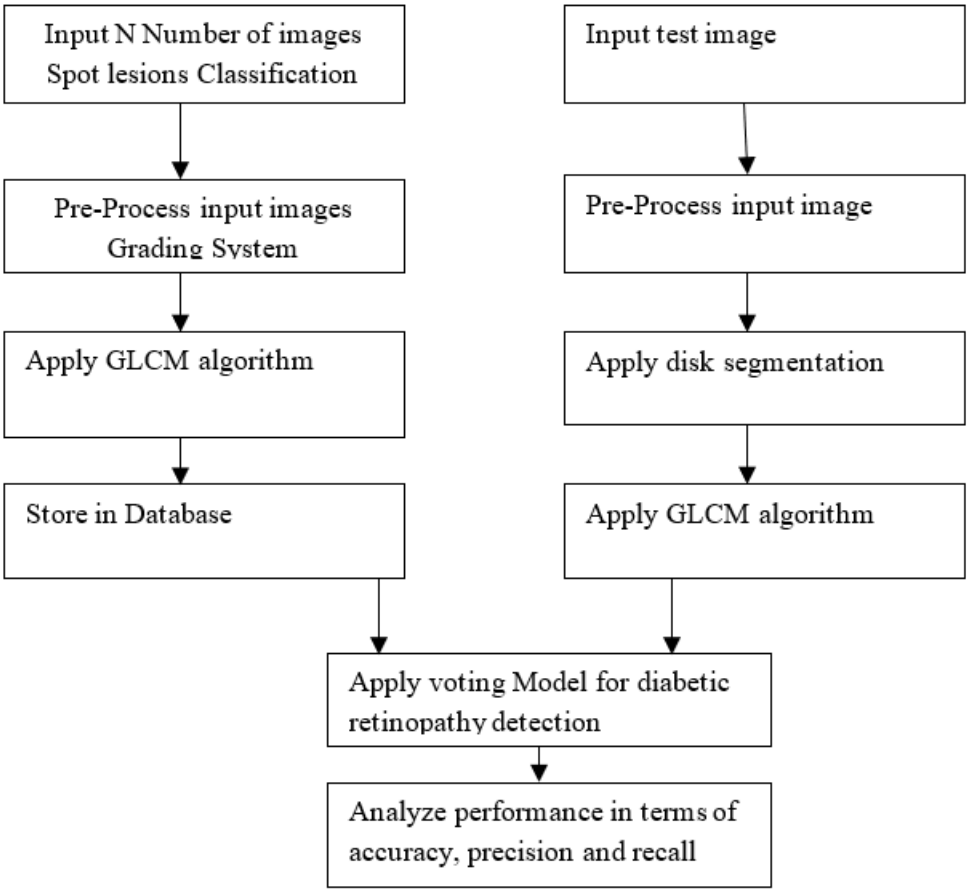

Figure 2: Proposed Methodology

Result and Discussion

To Diabetic Retinopathy detection technique which is proposed in this research work have various steps which are input of data, to segment images, extract features and classify DR. The Diabetic-1 dataset is executed in testing the suggested approach. The MATLAB tool is used for the implementation, Image processing and Machine learning toolboxes are used to accomplish this work. The proposed model is validated and it is proved that it best is best for brain tumor detection as compared to other models like KNN, SVM and RF.

The testing of this approach is done concerning certain metrics: accuracy, precision, recall and execution time. The performance is examined by considering accuracy, precision and recall and the details are as follow:

a. Accuracy: The accuracy is the parameter which define how much your system is accurate in classification. The equation number 5 describes the accuracy in which 'n' is the total number of samples and 't' is the correctly classified samples.

This parameter is mathematical represented as:

$$A_i = \frac{t}{n} \cdot 100 - -(5)$$

b. Precision: The precision defined the acceptability of the of the accuracy of the suggested approach. The qualtion number 6 describe precision formula which 'TP' means true positive value and 'FP' means false positive.

Precision= TP/TP+FP---(6)

c. Recall: The recall parameter define that how many true positive values are found from the output. The recall is described by the equation 7 in which 'TP' is true positive and 'FN' is the false negative.

Recall= TP/TP+FN----(7)

Table 1: KNN Classifier Performance Analysis

Parameter	Value
Accuracy	83.38 percent
Precision	42.5 percent
Recall	94.4 percent

Table 2: Random Forest Classifier Performance Analysis

Parameter	Value
Accuracy	80.96 percent
Precision	59.16 percent
Recall	83.8 percent

Table 3: SVM Classifier Performance Analysis

Parameter	Value
Accuracy	79.35 percent
Precision	63.33 percent
Recall	81.2 percent

Table 4: Voting Classifier Performance Analysis

Parameter	Value
Accuracy	89.35 percent
Precision	73.33 percent
Recall	94.8 percent

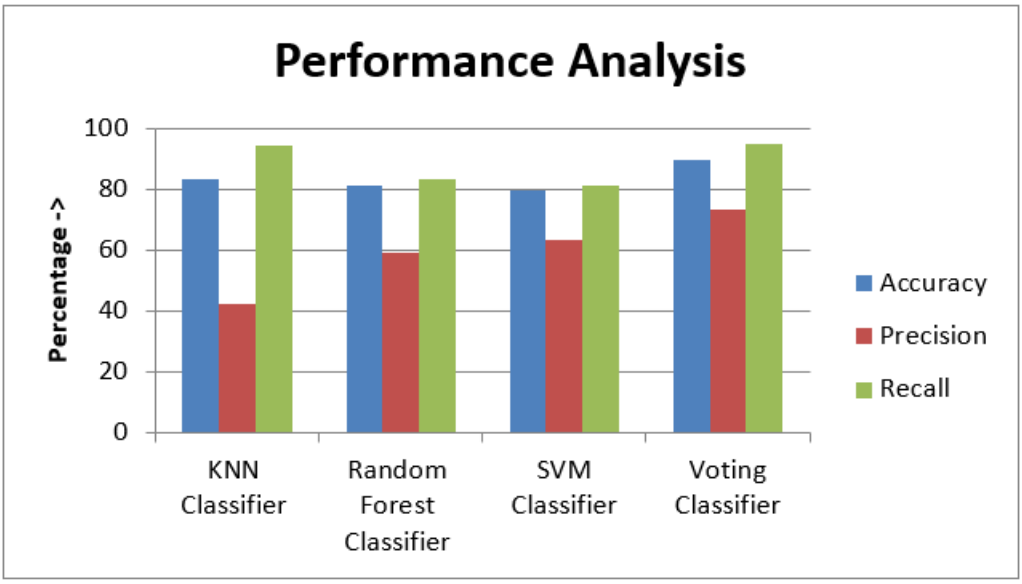

Figure 3: Performance Analysis

The figure 3 reveals the comparison of different classification algorithms namely KNN, RF, SVM and Voting Classifiers are compared concerning accuracy, precision and recall. This depicted that voting classifier performed more effectively in comparison with other classifiers. The voting classifier give accuracy of 89.35 percent, precision value of 73.33 percent and recall value of 94.8 percent

Conclusion

Diabetic Retinopathy becomes a major health problem. This disease leads to damage the bloods vessels of retina and the DR disease takes place. The people suffered from high blood sugar levels and diabetes of 1 or 2 type are more prone to this disease. Only mild vision loss problems are found at the initial phase of this disorder. But at the last stage complete a patient can face blindness. A comparative analysis is conducted in this approach against KNN, SVM and random forest concerning accuracy, precision and recall. The results indicated that the proposed model give maximum accuracy with 89.35 percent as compared to SVM,KNN, random forest which gave accuracy of 79.35,83.38, 80.96 percent respectively. The results shows that proposed model give approx 6 percent result improvement for the brain tumor detection. In future, RNN technique can be applied in future for the diabetic retinopathy detection.

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