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Microaneurysms Detection in Fundus Retinal Images Using Image Processing and Machine Learning

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Abstract—

Diabetic retinopathy is spreading at very faster rate across the globe. The opthalmic appearance of diabetes is called as Diabetic retinopathy, and the people who have diabetes are at high risk to lost their visual sense by this diabetic retinopathy. If a people have diabetes over a long time then up to 80% of people lean to evolve diabetic retinopathy. Micro vascular complication is also the most frequent cause of diabetic retinopathy. Micro vascular damage becomes manifest,is the very first point in the eye. All though there are number of techniques for diabetic retinopathy treatment like lase treatment. But primal detection of this play a vital tole in the successful and complete treatment. Human eye consist of number of component like cornea,pupil,lens,fovea,optic nerve,retina iris etc. All the component have their importance but Retina is the most essence part of the human eye. Diabetic retinopathy affect the retina and their functioning. Retina has blood vessels for blood circulation in the eye. In diabetic retinopathy blood vessels are deform and have some defects that cause the complete blindness and vision-threatening. The changes in vessels due to diabetic retinopathy bring forth lesions, which posterior the functioning of the photo acceptive cells . Fovea has the larger photosensitive cells, when the affected region reach to near the fovea serious condition occurs. At this stage vision-threatening is occurs because of eye pressure increases every time. Diabetic retinopathy detection in early stage is a great challenge because it does not have any symptoms and signs by which patient can know about it. The symptoms are shown at the stage where treatment is not useful and gave good results. There is need of high accuracy software which can detect the diabetic retinopathy at early stage, currently there is unavailability for screening software, the scanning is done by eye specialized doctor. In this paper we are proposing the solution for early stage detection of DR. DIARETDB1 database is used for all experiment and testing. In the process of DR detection steps like preprocessing, candidate extraction and feature extraction used.

Keywords—Diabetic retinopathy, Image-processing, Microaneurysm, Machine learning,Python .

I. INTRODUCTION (*HEADING 1*)

The unfitness of the human organism to digest the sugar in the blood is called as Diabetes,which is the combination of number of diseases . This condition is occurs due to the following reasons, first is deficiency of insulin, and second is the improper reaction of the organism to the insulin produced by the organism. This illness affected 422 million of people till 2014. This is the only diseases which took larger than 1.5 million of lives only as in the end of 2012, because of this it become the major causes of death in all over the world.

We can say that the Diabetes is a origination of a number of diseases,which are not the cause of death maximum times but produced serious complications. There are number of complications due to the diabetes out of which diabetic retinopathy is the most prominent. Diabetic retinopathy is a serious diseases of eyes in which the blood vessels of the retina become irregular in shape and size some times they leak out fluid and make lesions on the retina surface of human eye. Diabetic retinopathy became the cause of death ,complete blindness and some time the reason behind the vision impairment. All these causes are depend upon the severity of the diabetic retinopathy.

In DR retinal blood vessels are destroyed mostly because of high diabetes. The difficulty with DR, it is not detected in initial stages. In later stages symptoms starts like blurr vision and in advance stage complete vision loss occur.

NDPR (Non – Proliferative Diabetic Retinopathy) is the stage with presence of MA and haemorrhages.

In later stage abnormal growth of vessels called Proliferative Diabetic Restinopathy.

Below are the example of health eye and eye with diabetic retinopathy.

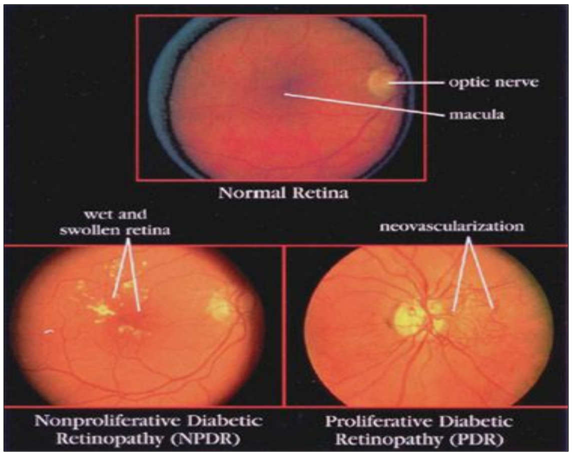


Figure 1.1 Fundus images of a normal retina, NPDR and PDR[25]

II. LITERATURE REVIEW

There are mainly three steps used for the detection of MA In first steps the images preprocessing done, in second step the locations of possible MA are extracted and in last step feature extraction and classification methods are used.

Dashtbozorg Others [2] the gradient weighting method, thresholding methods are used for image preprocessing. This step is very important for error filtering. The parameters those are extracted from image are shape, intensity and local converge filters.

Habib et. al. [3] In this research work ensemble classifier approach is use for finding the MA in retina images. Gaussian filter is used for candidate detection and after detection classification is performed. This method is helpful in finding out the false positive cases.

Su Wang, et. al [4], have been presented a method for microaneurysm detection in which they apply Singular Spectrum Analysis. With the microaneurysms detection they also extracted exudate and optic nerve by using the some preprocessing techniques like segmentation thresholding, and morphological operations and achieved their goal.

Antal et. al. [5] In this work method is developed for categorization and microaneurysm detection. Messidor database is used for this work, 89% AUC has been achieved in last classification stage of process.

Chandrakumar et al. [6], The author detect microaneurysm by applying the deep learning approaches and some preprocessing techniques of digital image processing and get some better results in the form of accuracy of 94-96 %.

Figueiredo J et. al. [7] For deriving contextual and numerical feature binary classifier used. Several wavelet bands analysis and it used the common features of Hessian multiscale and variational segmentation. This method has obtained 89.3% specificity and sensitivity obtained 94%.

J Larsent et. al. [8] Author used the preprocessing methods before using the various image processing techniques. By using the image processing MA and haemorrhage detected. The results achieved are 98% sensitivity and specificity close to 72%.

Ram S et. al. [9] For early detection of retinopathy clutter rejection method is used, author removed the clutters in initial stage. similarity score which is based on true MA similarity. Data set sused are ROC (Retinopathy Online Challenge), DIARETDB. Using DIARETDB1 88.56% specificity and sensitivity obtained. Author found out that in comparison of CRIAS data set ROC gave more sensitivity.

Neimeijer et. al. [10] KNN method separate MA from non MA images. The proposed method for candidate find out was based on pixel techniques. Each pixel has different intensity so it varies from MA section to non MA section. Author also used morphological approach. Using above methods and intensity gradient features are extracted.

Lazar J [11] Here author used different approach rotation based cross sectional, here details selected are local max pixel after peak finding technique is done.

Zhang Zang [12] Here the filter used was multi scale gaussian based filter , this filter identified the MA and Non MA section based on intensity of pixel. The classification methods after filtering were Sparse representation class and dictionary based learning. After classification vessel extraction done using image processing techniques.

Akram et. al. [13] The name of the library is Theano. They used two type of classification one for two class and other for the five class and achieved the accuracy of 95% and 85% respectively. Using filter banks for MA detection.

After extracting the MA at first stage, in second stage the parameter for filtering used are shape, pixel intensity, color etc.

Seoud I et. al. [14]

In this work method based on color and shape feature are used for finding MA and haemorrhage. In this work author used six extensive datasets. The results were different for different data sets accuracy 89% with MESSIDOR, froc score for ROC data set was 0.421.

Sumathy [15] In this work author suggested MA detection based on number of MA detected. The more number of MA found will have more possibility of actual MA. In preprocessing stage author extracted the green channel from image and performed the feature extraction method on that. Various image processing techniques like histogram, noise removal, median filter used. MA detected and removed from image. The segmentation of blood vessel are done using morphological methods such as top hat filter then filtering by Gaussian filter. The current method has improvement in results but there are limiting factors like method is based on physical factors shape, intensity, change in illumination , compression values etc. MA shape location, size also matter for finding out the MA in retina images.

Wen Cao et al. in [16], they used small patches of diabetic images for this purpose. The apply traditional machine learning approach on DB1 and ROC database to accomplished their goal. They also used dimensionality reduction techniques like Principal Component Analysis and RF feature importance .By using all these they achieved better result then the deep learning approach are used in second literature.

J. Shan et al. in [17], In this paper the author apply deep learning techniques for the detectio of micro-aneurysms. For this they used Stacked Sparse Auto Encoder(SSAE) and softmax classifier and get AUC 96.2% and F-measure 91.3% respectively.

R Murugan et al. In [18] , present an automated system that bring forth to detect the MA from the color fundus images. They used intensity variations and adaptive histogram equalization techniques for the preprocessing. The author also used the segmentation approach for finding the microaneurysms.

M. V. Anifa Jini et al.[19] The proposed method is used Random Transform (RT), Top-hat Transform. They apply top-hat transformation and sequential filtering for background detection. They utilized the RT technique and also divided the image into sub regions for segmentation.

Lin Li Juan Shan[20], In the proposed method they used the novel approach called as region growing. An automated system is designed in this research to identify the occurrence of MA and non MA. . For this purpose the used Diabetic Retinopathy dataset (DIARETDB1) . They attend the measures as sensitivity of 86.6%, specificity of 96.3%, and an accuracy of 93.9%.

P M D S Pallawala et al.[21], They presented the noble approach for detection of micro-aneurysms by using eigenvector affinity matrix to carve out segmentation from retina images. The area of micro-aneurysms is very small because of that it is difficult to detect and there is similarity between other abnormalities. Authors achieved more then 90 percent accuracy with 90 images dataset.

Ratul Ghosh Kuntal Ghosh Sanjit Maitra[22],

In this work author suggested new technique CNN for diabetic retinopathy detection from color fundus images. They first did the denoising on images to detect the DR and by using python library and GPU system. The name of the library is Theano. They used two type of classification one for two class and other for the five class and achieved the accuracy of 95% and 85% respectively on kaggle data set.

Shubhi Srivastava et al. [23], They proposed detection of micro-aneurysms and hemorrhages form the color images by suing computer vision. They find the all microaneurysms and hemorrhages candidates by using Morphological operations. For blood vessels detection they apply Gabor filter and for features extration SVM are used .The accuracy of 93% and 91.8% is achieved by using DIARETDBI and MESSIDOR datasets.

Ravi Kamble et al.[24], They presents a novel technique for the detection of microaneurysm by using the intensity variation and local rank filtering. Guided filters with gradient are used for the vessels extractions. They identified MA by using different data sets like Optha, DIARETDBI and MESSIDOR.

III. METHODOLOGY

To detect diabetic retinopathy at early stage first and foremost symptoms is microaneurysm, so to achieve this we have to apply some systematic approach. The systematic approach consists of some connected sequence to do that. So following are the step by step process which we follow in this method for Microaneurysm detection.

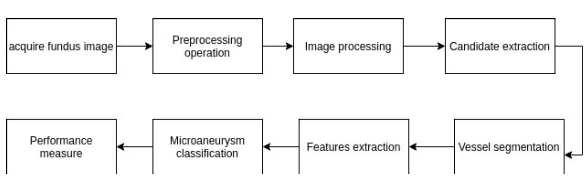


Figure 3.1 :Step sequence for MA detection

Database

Database can be defined as the collection of records that contains the useful information such as medical record approved by a set of instructions on a particular system. In this work we have used DIRETDB1 data set which contain total 89 fundus images. The data is completely annotated and tested by the specialist and validated by the ground truth of the images.

Software and Tools

The complete work is performed on Python3 language and Anaconda distribution is used for this, which provide the data science packages applicable for Windows, Linux and OS. In the proposed work we have used Ubuntu16.04 and Jupyter lab ,which is a web based user interface and can be work as an IDE. For all the image processing operations Python libraries are used like OpenCV,Skimages. Some other libraries used in this work are Numpy,Pandas, Matplotlib etc.

Retinal Image Acquisition

A specialized camera called a fundus camera is used for acquiring retinal images. There are two types of fundus cameras: Mydriatic and Non- mydriatic. The mydriatic camera requires pupil dilation but gives better quality fundus images. Whereas, the non-mydriatic camera is smaller, easy to operate, and does not need dilation of the pupil. For diagnostic purposes, color fundus images(FI), red-free images, fluorescein angiograms(FA), and optical coherence tomography (OCT) are used.

The only way to detect the progression of DR is through eye screening. In FA, Sodium fluorescent dye is injected into the bloodstream which highlights the retinal blood vessels so that they can be photographed. Abnormalities like the growth of new blood vessels, leakages or blockages, hemorrhages, and MAs are better visible in FA than in FI. But certain side-effects are associated with FA like pupil remains dilated for almost twelve hours after performing tests, the color of urine becomes orange, darker for some days, nausea, vomiting, fainting, swelled hives, etc. Hence FI is preferred nowadays.

In OCT, eye drops are put in the patient's eyes to dilate and widen the pupil for easier retinal examination. After eye dilation, the candidate have to sit in front of the OCT device with their head balance on a support. OCT is a long-familiar method that gives detailed images of the retina (the inner layer of the interior eye). It accurately detect, monitor, and control the changes to the retina surface. OCT is the single way to get the retina's internal structure of image. Others only give images of retinal surface structures. There were many other techniques related to imaging like confocal micoscope scanning, color doper technique, magnetic resonance of images and computed tomography used for eye health check.

Pre-processing

The performance of lesion detection is proportional to image quality. Fundus images often have very low contrast and poor illumination, which usually makes the task of feature extraction complicated. Hence, it needs to be preprocessed to reduce noise and enhance image quality. Preprocessing is done for enhancing required features while suppressing unwanted information. Often used preprocessing techniques are:

• Non-uniform illumination correction.
• Contrast enhancement.

Non-uniform illumination correction

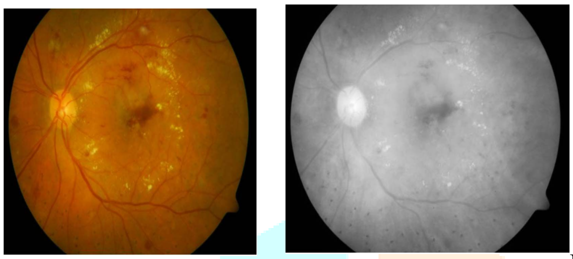
Non-uniform illumination is the most common issue in fundus images. It is because of improper focus, patient movement, variations in reflections, and camera differences. Usually, retinal images have high contrast in the middle as compared to corners. As per Hoover and Goldbaum [3], shade variations in an image are because of this non-uniform illumination, It thereby reduces image analysis efficiency. Shade correction is applied to remove this.

Background image is subtracted from green channel extracted images.

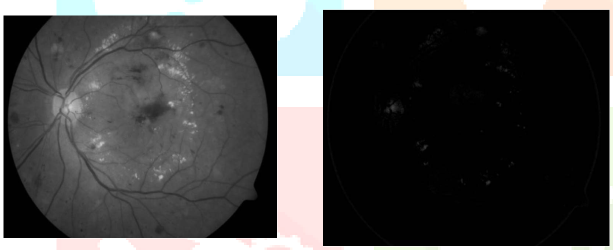
Contrast enhancement

Images acquired with the fundus camera often have low contrast. Also, it is to a great extent affected by factors that are challenging to control them. Adaptive contrast enhancement overcomes this problem. Hence, contrast enhancement, normalization is a must before proceeding with further diagnosis. [6],[7] uses contrast enhancement and shade correction is used by [8],[9] as a preprocessing step. Some algorithms for red lesion detection need no preprocessing such as deep learning and dictionary learning.

Detection and Elimination of Anatomical Structures like Blood Vessels and Optic Disc



MAs never appear on blood vessels, but many red/dark spots within a retinal vessel can be MA candidates. For reducing false MA detection, anatomical structures like blood vessels (BV) and optic disc (OD)



CFI (a) actual colorful image, (b) Image with Red , (c) Image with Green, and (d) Image with Blue [2]

Red Lesion Detection and Feature Extraction

After detecting and eliminating anatomical structures from the retinal image left-overs are lesions: dark or bright. Dark lesions are MA and HM. MA and HM are together also termed red lesions; because they appear red/ dark in FI. Several algorithms for red lesion detection are described in the literature. Reviewed algorithms can be broadly divided into two: one in which MAs are extracted in a single step, the other detects possible MA candidates first, and applies feature extraction to finally detect true Mas. Detailed literature review is presented in chapter 2 discusses several techniques such as morphology, filtering, pixel classification are used for red lesion detection. A decision on algorithm inclusion, in particular, the approach is done based on the technique used for lesion extraction.

Performance Parameter Measurement

There are several performance matrices calculated to get the assessment. In the red lesion detection system there are number of performance matrices such as

a) Sensitivity denoted with symbol (SN),
b) Specificity denoted with symbol (SP),
c) accuracy denoted with symbol (ACC)
d) Receiver Operating Characteristics

Usually sensitivity test conducted for faulty eyes or eyes with disease and specificity measurement for eyes not having disease. This will negative test results if there is disease. Huge values of Sensitivity and Specificity are thoughtful better for diagnosis.

$$\text{S.N.} = \frac{TP}{TP+FN}$$

$$\text{S.P.} = \frac{TN}{TN+FP}$$

$$\text{A.C.C} = \frac{TN+TP}{TN+TP+FN+FP}$$

Here is the representation used above, TP (True Positive): If proportion abnormal FI detected abnormal only, faulty detected as faulty.
TN (true negative): If Normal FI detected as normal, means positive is detected as positive
FP (false positives): Positive case detected negative.
FN (false negatives): if negative case detected positive

Specificity considers as valid negative and Sensitivity consider as valid positive.
The ratio of TPR and FPR calculates the TPR

$$\text{TPR} = \frac{TP}{TP+FN}$$

and

$$\text{TPR} = \frac{FP}{FP+TN}$$

The above equations interpret that TPR is the same as sensitivity and FPR as Specificity.
ROC made after calculating the all combination of TPR and FPR. A single point on the receiver operating characteristic curve shows the One TPR and one FPR together . Both are inversely proportional to each other as sensitivity increases then specificity decreases. The area under the curve (AUC) measures the accuracy of the method used for detection of microaneurysm. As larger AUC as better in diagnostic accuracy. In any automated red lesion detection method the value of AUC, more than 0.8 is considered good i.e comparable with human experts Table 1.2 gives the relationship between AUC and accuracy

Relationship between Accuracy and AUC[5]

AUC Range
Accuracy→ In the range of 0.9 to 1.0
Excellent → Range of 0.8 to 0.9
Good → Range of 0.7 to 0.8
Fair → Range of 0.6 to 0.7
Poor→ Range of 0.5 to 0.6
All classifier performance can be represented in curve known as ROC (Receiver operating Charateristic) curve. This curve is the representation of different threshold values at TPR and FPR. As per std TPR should be denoted on Y and FPR on X axis.

IV EXPERIMENTAL DETAILS

DIARETDB1 dataset is used for the experiments, which have total 89 images . After applying the preprocessing operation on the image021 of the DIARETDB1 database ,we have got the following resulted images

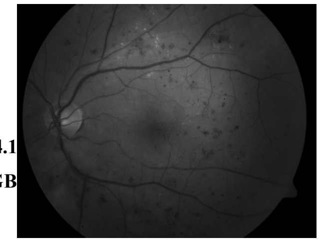


Fig 4.1 (a) RGB Image and (b) Green Channel Image

To obtain the gamma corrected image we have to used the following equation:

$O = I \wedge (1/G)$ -------(1)

I→ Input image, O→ Output image, G→Gamma value . Figure 4.2 (a), (b) and (c) shows the images for the different gamma values.

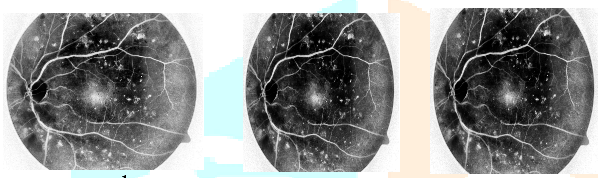


Fig 4.2 (a) G = 2, (b) G = 3and (c) G = 5

After this Adaptive histogram equalization is applied with clipLimit=25.0 and tileGridSize=(8,8). After that 2D filtering with 13x13 kernel and otsu thresholding with min 125 and maximum 255 limit is applied. The resulted image is shown below

Fig 4.3 (a)Image after CLAHE (b) Image after 2D filtering, (c) Image of Blood vessel Segmentation

Structuring operations are applied, Top hat with the kernel size 7x7 and opening with the kernel size 5x5, resulted images are shown below

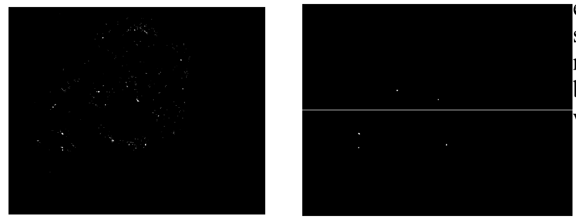


Fig 4.5 (a) Image after Top hat operation (b) Image after opening operation

After extracting the possible MA from the image there are some cause of misclassification. As we applied some noise reduction operation in spite of that there are some chances for the noise that could be the erroneous MA detection which is FPs. As we know that MA has irregular shape and size with red color it can misclassification of Fns. So distinguish between MA and HM shape features are used. As we know that MA is present at the end of the bloodvesels and can we remove at the time of BV extraction ,there could be the chance of presence of HM.

So for the identification of true MAs we have to apply some features extraction. F

In this proposed research we are extracting the Following features. Feature extraction play the important role for the next step and final step that is classification. Due to the different shape , size and color of the MAs in this method we extracting the following features

(I) Total number of candidate regions: => Total number of candidate regions = Total possible MA regions

We used blob_log function with following values

a) Max Sigma = 25

b) num_sigma = 10

c) threshold = 0.85

blob_log is the std method defined in skimage library. This is the most accurate approach to get the bright blobs on dark background. Blog log function computes the Laplacian of Gaussian image with increasing std deviation and push them in cube. Bright locations are the maximas in this cube. If we need to detect the large blobs this method will be slower because of larger kernel size in convolution. The other functions are Difference of Gaussian (DoG) and Determinant of Hessian (DoH).

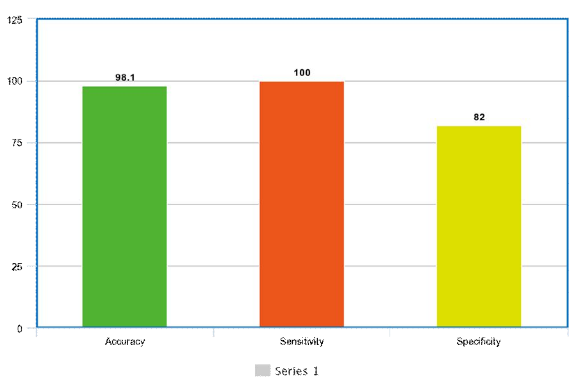
Image Details	MA in Ground truth	MA in our result
Image001	22	22
Image002	12	11
Image003	36	34
Image004	25	24
Image005	30	30
Image006	17	17
Image007	47	45
Image008	19	17
Image009	39	40
Image010	51	51

Table.4.1 MA validated with ground truth

After extracting the proposed features from the image machine learning algorithms are used for the classification of MA and non-MA. There are number of machine classify for this task nut in this method we will used Naive Bays(NV), Random forest (RF), support vector machine(SVM) and K-nearest neighbor(KNN). These four classify are used for the classification of MA and non-MA in the proposed work.

Naive Bayes

This algorithm is based on the Bayesian theory and comes under the supervised learning. The basic principle of naive bayes is features are not dependent on each other. The Naive Bayes calculate two probabilities one is prior probability and another is conditional probability of class from training samples [6]



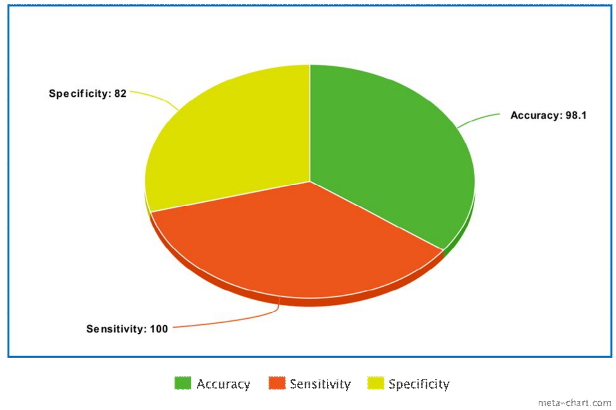


Figure 4.1 : a) Accuracy, specificity and Sensitivity bar chart b) Accuracy, specificity and Sensitivity pi chart

K Nearest Neighbor

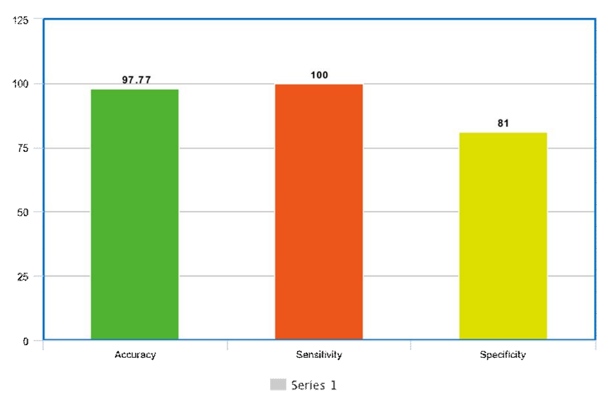
KNN commonly name as lazy learning technique of machine learning. It depends on training sample greatly. Since it largely depends on training sample KNN also called as mechanical learning. Below are the important points related to KNN

a) KNN does not need model, it is non parametric supervised learning method.

b) It calculates distance among test samples and training samples, it find K number of closest sample to test sample frm training database.

c) KNN use majority voting rule and classify test sample into class of K nearest samples.

Following parameters used:



Test_size = 0.2, Random_state = 41, N_neighbours = 5

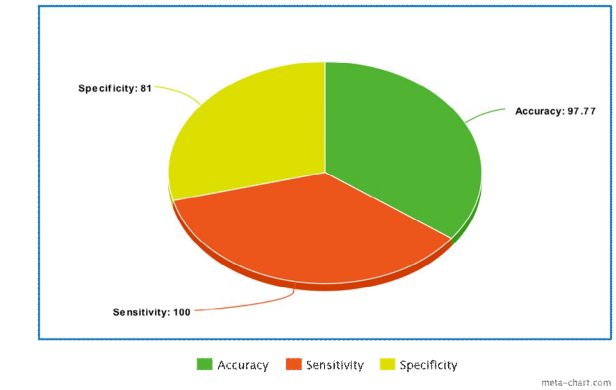
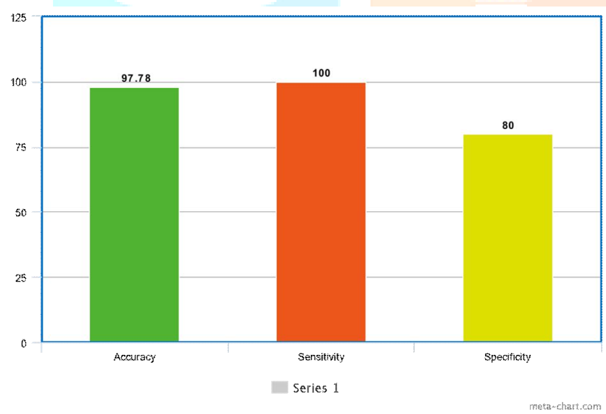


Figure 4.4.2 : a) Accuracy, specificity and Sensitivity bar chart b) Accuracy, specificity and Sensitivity pi chart

Support Vector Machine

SVM is used mainly for solving the problem related to data classification, it is supervised learning. SVM divide the samples into different categories based on maximum margin hyperplane. If the data problem is related to linearly inseparable than SV use kernel functions . The main kernel function includes Radical basis function (RBF), linear and polynomial data and sigmoid. RBF kernel used for SVM.



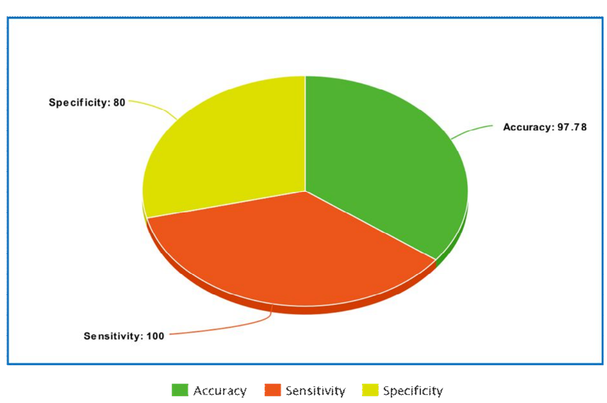


Figure 4.4.3 : a) Accuracy, specificity and Sensitivity bar chart b) Accuracy, specificity and Sensitivity pi chart

V. RESULTS AND DISCUSSION

The exeperiment conducted in this paper are examined by the calulation of accuracy of MA detection is tested on three metrices Accuracy, Sensitivity and Specificity. For the proposed work Accuracy,Sensitivity and Specificity are calculate for three classifyers KNN, SVM and Naive Bayesian.

The Accuracy,Sensitivity and Specificity of the proposed system are given as follows:

Classifier	Accuracy	Sensitivity	Specificity
KNN	97.77	100	81
SVF	97.78	100	80
Navie Bays	98.1	100	82

Future works

Future work can be estimated by keeping the limitation of this work in mind, which is explained above. In the subsequent work , more accurate and appropriate denoising operations should be take place in the preprocessing stage. To improve the generalization of this method more datasets should be used that can cover the more heterogeneous samples are required for the validation. For the consideration of clinical aspects and effects it should include some sample from the hospitals for the clinical validation and satisfactionn.

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