An Efficient Machine Learning Technique on Retina Blood Vessel Datasets

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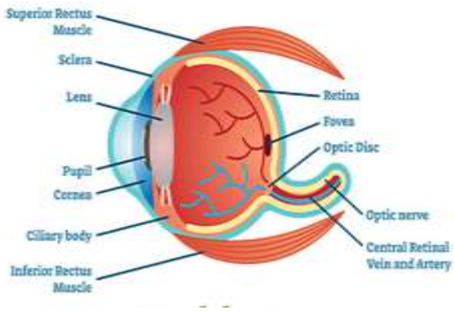
***Abstract*:** In recent years, an automated retinal vessel segmentation technology has become an essential tool for diagnosis and identification of the disease. However, still, various issues have been faced during retinal vessel segmentation like as low accuracy, contrast, and illumination. These problems are due to symmetrical and asymmetrical structures among blood vessels that may be complex. Hence, vigorous vessel segmentation of the retina is significant for improving the diagnosis of the diseases like as diabetic retinopathy and vein occlusions. An accurate segmentation process provides a suitable contrast of the retinal blood vessels that offer the suggestion about the ophthalmologic disease for the correct diagnosis of the disease by decreasing the error rate. In this research, an automated retinal vessel segmentation method has been developed using machine learning methods which include; supervised and unsupervised methods. In the supervised model, some of the methods are perceptron and ANN (Artificial Neural Network), support vector machine (SVM). On another hand, the unsupervised technique is a clustering process, k nearest neighbor (KNN) method, and Hidden Markov Model (HMM) method. In addition, the three data sets are also explained, namely; STARE, CHASE and DRIVE dataset. Moreover, an overview of the retinal fundus imaging is also described. Along with that, a brief description of diabetic retinopathy (DR) is also elaborated. In addition to that, the workflow process of the retinal vessel segmentation is also considered with different steps which are image acquisition, pre-processing, optic papilla elimination with vessel enhancement and fusion process. This research mainly evaluation of the modern and advanced supervised and unsupervised blood vessel segmentation method that is based on various classifiers namely support vector machine classifier, k-nearest neighbor, Hidden Markov Model and artificial neural network..

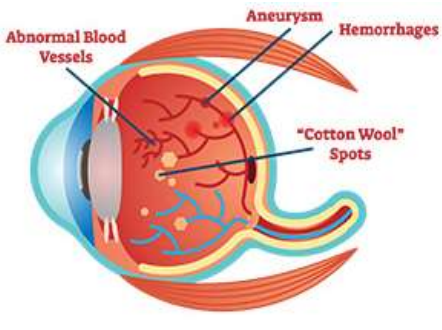
***Keywords* :** Retinal Vessel Segmentation, Supervised and Unsupervised Methods, Diabetic Retinopathy, Retinal Fundus Imaging.

I. INTRODUCTION

Currently, the major reason of the loss of sight among the people is the occurrence of the eye infections like as DR (diabetic retinopathy) and DM (diabetic maculopathy) . Generally, DM is the large pre-clinical stage where the visual perception was not influenced and the time when a person lost the vision may not be recovered. Hence, it becomes necessary to prevent the growth of the disease and protects the vision approach [1]. So, the experimental analysis of the geometrical features like as vessel diameter, area length and angles has become the source of the medicinal benefits correlated to timely analysis and efficient observing of retinal pathology. Retinal picture assessment by ophthalmologists is a significant stage for the detection of the retinal pathology (RP). In addition, the picture segmentation has been a comprehensive application during the time before 1990's. Currently, large AI based methods like as supervised techniques have became common in this region. Pattern identification and machine learning (ML) techniques are very useful because of their growth in medicinal picture analysis scheme [2]. Conversely, the robust computer aided technique for medicinal picture analysis was challenging approach because of the complication and heterogeneity of retina pictures. Hence, it becomes significant to diagnose the diseases by finding more differentiated features of the pictures. DR (Diabetic retinopathy) is the main eye infections that influenced the retina. The situations caused due to difficulties of the diabetes that may also lead to blindness. The non standard level of this disease may cause this disease [3].



(i) Healthy Eye



(ii) Diabetic Eye

Fig .1 Structural View Of Normal And Diabetic Eye Image [7]

However, the weakening of the retinal blood vessels, convoyed by the structural changes in retina, is named as diabetic retinopathy. Generally, DR may pass through a sequence of the changes like as leakage and closure. These changes may pass through from stage to other stage. Whereas, some of the stages of the diabetic retinopathy includes [4],

A. Minor Non-Profirative Retinopathy:

At the earlier stage , the microaneurysms take place. These are mainly of smaller balloon like size that are swelling in tiny blood vessels.

B. Sensible Non-Profirative Retinopathy:

With the growth of the eye infections, few of the blood vessels that nurture the retina vessels are congested.

C. Serious Non-Profirative Retinopathy:

In this stage, large number of the blood vessels is congested, depriving various regions of the retina with the delivery of the blood. Generally, the retina areas forwards signals to the body to develop blood vessels for the nourishment process.

D. Profilerative Retinopathy:

During this phase, the signals are forwarded by the retina for the nurture process which activate the development of the new blood vessels. In this stage, the novel blood vessels are on standard and delicate. It develops alongside the retina and towards the area of the strong, glassy gel that resides in the eye. In this disease, if the leakage of the blood increase then, there may be severe vision loss.

II. RETINA FUNDUS IMAGING AND PROCESS

It is the process in which two dimensional demonstration of two dimensional retina semi-transparent soft tissue is predictable on the image plane is achieved through reflected light. However, the method that leads in two dimensional picture, in which picture intensities demonstrates the number of the reflected amount of light, it called as fundus imaging [5]. Generally, various methods of the fundus imaging are categorised as,

A. Fundus Imaging (Red Free Imaging):

Generally, the picture intensities demonstrates the number of reflected light of specified waveband.

B. Color Fundus Imaging:

In this, the picture intensity demonstrate the quantity of the redirected light R,G,B waveband , as recognised through spectral sensitivity of the sensors [6].

C. Stere- Fundus Imaging:

Picture intensity demonstrates the number of the redirected light from more than two vision angles for complexity resolution.

D. Hyper-Spectral Imaging:

The picture intensity demonstrates the number of redirected light of numerous specified wavelength bands.

E. Slo (Scanned Laser Ophthalmoscopy):

The image intensity demonstrate the redirected light of unique wavelength laser light achieved in required time series.

Generally, the discovery of the blood vessels (RV) in retinal blood (RB) picture is significant for the better segmentation. Previous to segmentation method, image processing (IP) is essential to eliminate the influence of the irregular noise and brightness along with enhancing the contrast among the contextual and the retinal blood vessels(RBV) [9]. The improved picture is segmented through segmentation method in which the edge map is achieved by threshold process. The given figure 2 determined the segmentation of retinal blood vessels.

A. Image Acquisition And Pre-Processing:

Initially read the input picture of various dimensions. In addition, retinal picture is improved through adaptive histogram method to improve the blood vessels [11]. After that, retina fundus picture is segmented in to three elements like as, red, green and blue channel. Generally, green channel is highly delicate to blood vessels. However, this channel is measured for the identification and splitting up of RBV's from retinal picture.

B. Optic Papilla Elimination:

n this method, create the structured component of the dimension 25x25 with zero digits. Then, hat conversion is applied by structuring component [12]. Then, the green channel is threshold with the values to create mask. In addition, the other structuring component is created with the dimensions of ones. Besides, applied the hat transform with single structure component. The red and blue channel of bottom hat is assigned from one to zero. Improve the contrast of green channel bottom hat values. Eliminate the pixel intensity rate in green bottom hat. Then, initialization of the novel matrix with zeros of the picture.

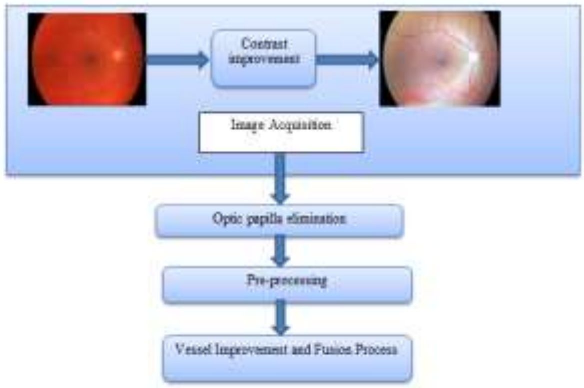


Fig.2. Work Flow Process of Vessel Segmentation [10]

C. Vessel Improvement and Fusion Process

In this method , multiple scale vessel improvement approach to novel green values with scale rates of improved vessel. After that, binarize the improved vessel picture using adaptive threshold process [13] . In addition, the filtration is done through the morphological operations. And, then the fusion of the improved vessel and filtration of the area is done. Lastly, the fused picture is converted into binary picture and segmented picure is received.In the above process, threshold value is fixed that depends on the input picture for variant datasets to have an improved segmentation of the image.

III. RELATED WORK

Yavuz, Z. et al., 2015[14] proposed study on the blood vessel breakdown of the fundus pictures. Initially, the pre-processing was performed and after that multiscale frantic filter was applied to improve blood vessels. In addition, fuzzy c mean clustering was utilised to achieve double blood vessel picture. They used binary retinal fundus picture dataset namely STARE and DRIVE to consider the performance of the scheme. Lastly, they achieved the accuracy up to 99.95% for STARE database and 99% for DRIVE database. ***Wankhede, P. R et al.,2015[15]*** presented research on new technique for automated segmentation of blood vessel utilising graphical cut technique. Firstly, they applied mean-filter , convolution by Gaussian-kernel , shade rectification, top hot conversion as pre-processing stage for improvement of blood vessel. It mainly improve retina pictures, While overwhelm the noise and non-vessel structural design storing vessel data. Afterwards, vascular structural design was eliminated utilising graphical cut segmentation. The planned technique was tested on freely available DRIVE database. Experimental analysis was done and compared with other techniques. The data rates was acquired with new technique for region below curve , accuracy was 0.9605, sensitivity was 0.7261 and specificity was 0.98. However, the performance was comparable that showed the efficiency of technique enhancing the segmentation outcome and identified blood vessels in accurate way. ***Yao, Z. et al., 2016 [16]*** implemented a convolution neural network (CNN) based blood vessel segmentation approach. Every pixel along with the neighbour of fundus picture was selected by CNN. The primary segmentation outcome of fundus pictures was developed by two steps binarization and morphological process correspondingly. This algorithm was tested on DRIVE database. The specificity was 0.96, sensitivity was 0.773 that was nearest to manual marginal note. The sensitivity was 2% better that was found in current studies. The CNN technique improved the division of the blood vessels(BV) efficiently. For improving the accuracy of blood vessels segmentation in fundus pictures, CNN was implemented. It was estimated that the test outcome on DRIVE dataset showed the efficiency of planned blood vessel segmentation approach where the sensitivity was almost better comparable to human viewer. ***Ling, C et al.,2019[17]*** concerned blood vessel division that depends on Markov model(MM) in wavelet domain. The two method needs, where available vein of plasma and integrality was reserved in to justification at same time for division outcome. However, for improving the blood vessels veins the guided filter was employed to enhance the pictures of difference rate and improve vein information. After the pre-treatment , the retina pictures were eliminated blood vessels. On the basis of the DRIVE, STARE and FIRE dataset, simulation outcome were presented to represent the obtainability and efficiency of the planned segmentation technique. In this research they proposed a method of BV division that depends on Markov method in wavelet domain. ***Mankar, P. R et al., 2018 [18]*** proposed research on the process of the segmentation of the blood vessels. Generally, the blood vessels (BV) were divided through top hat and h maxima and also for classifying the CNN method that may be used to achieve accuracy (accu). The system was accomplished in such way that it sections the BV automatically and classified the atmospheric situation was standard or non-standard. Hence, the maximum graph processor unit where GPU scheme was utilised for training on large offered pictures and displayed the outcomes, and it worked for high level classification job. They has developed the approach on binary accessible dataset (DRIVE and STARE) . The performance metrics involved at the time of classification was accuracy, sensitivity and specificity. ***Li, M et al., 2017[19]*** developed a vigorous retina blood vessel segmentation technique that depends on the reinforcement localised descriptors. A new line group feature was established to capture the localised shape data of the vessels by engaging the dimension priority of the vessels that was robust to the variations in intensity level. Afterwards the localised intensity features were computed for every pixel and the morphological gradient characteristics was eliminated for improving the local edge of small vessels. Lastly, the group based feature (GBF), limited strength feature (LSF), and morphological gradient (MG) features were joined to get the re-enforcement localised descriptors. The planned re-enforcement localised descriptors consist large confined shape, strength and superiority of the vessels compared to previous local descriptors, that was more robust. After that, the feature extraction took place, and SVM was trained for blood vessel segmentation. Moreover, they developed a post-processing technique that depends on morphological re-building to link some irregular vessels and achieve more accurate segmentation outcome. Experimental analysis was done on two freely available dataset(DRIVE and STARE) represented that planned reinforcement localised descriptors performed better as compared to state of art technique. The tables 1 and 2 summarizes the various methods, dataset and parameter metrics are described.

Table 1: Various methods, Dataset And Parameter Metrics: Retina Blood Vessel Imaging

Author	**Year**	**Methods**	**Dataset and Parameters**
Yavuz, Z. et al., [14]	**2015**	FCM	STARE ACC = 95.95% DRIVE ACC = 95.95 %
Wankhede, P. R et al., [15]	**2015**	Graph Cut Method Mean Filter Gaussian Kernal Tap-hat Transformation	DRIVE ACC = 0.96% DRIVE SPEC = 0.98% DRIVE SENS = 0.721%
Yao, Z. et al., [16]	**2016**	CNN	DRIVE ACC = 93% DRIVE SPEC = 0.96% DRIVE SENS = 0.77 %
Ling, C et al.,2019[17]	**2019**	Markov Model Guided Filter Wavelet Domain	DRIVE STARE FIRE
Mankar, P. R et al., [18]	**2018**	CNN	STARE DRIVE
Li, M et al., [19]	**2017**	Re-inforcement local descriptor SVM	STARE ACC = 0.951% DRIVE ACC = 0.9626

IV. DIABETIC RETINOPATHY IMAGE DATABASES DESCRIPTION

Generally, the retina blood vessel segmentaion is processed on freely available datasets. Thoug h, there are various datasets like as drive, stare, aria, messidor and so forth. But, three types are explained below which are DRIVE, STARE and CHASE dataset [20].

A. DRIVE Retina Blood Vessel Image Database

The images are achieved through the screening of the diabetic retinapathy in netherland. There are 40 pitures captured by canon CR 5 digial camera utilising 8 bits per color plane along with resolution of 768* 584 pixels. It contains traing and testing sets with 20 pictures. The test sets consists 20 ground pictues that is segmented by medical experts and training set consisting 20 ground truth pictures manually segmented by medical specialists.

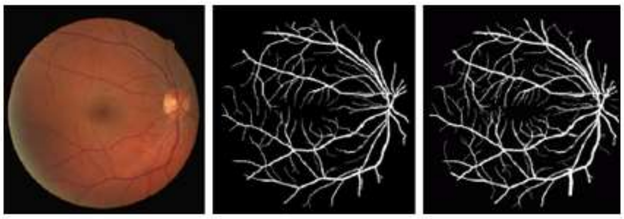


Fig. 3 Dataset image of DRIVE dataset

B. Stare Diabetic Retionapthy Database

The pictures are achieved from secreening of the DR in Netherland. Generally, 40 pictures are captured by canon CR5 digital camera using bit color plane with resolution of 768* 584 pixels. It also contain training and testing dataset by two medical specialists and training set with 20 ground truth pictures manually segmented by one medical specialists.

Fig. 4 Dataset image of STARE dataset

D. CHASE Retina Blood Image Dataset

This dataset consist the binary group of physically segmented monochrome-ground –truth (MGT) pictures by dual medical specialists. The manual segmented pictures by the social viewer are used as ground truth for computing of the performance of the designed approach [21].

Fig. 5 Dataset image of CHASE dataset

Methods	Purpose
FCM	Clustering Process
Graph Cut Method Mean Filter Gaussian Kernal Tap-hat Transformation	Segmentation and Extraction Filtration (Remove Noise) Edge Detection
CNN	Classification
Markov Model Guided Filter Wavelet Domain	Classification Filration Transformation
CNN	Classification
Re-inforcement local descriptor SVM	Extract Features Classification

Table 2. Summarize the several methods with purpose : Retina Blood Vessel Imaging

Table 3 described the different type of retina image dataset, image pixel size, image resolution and image format.

Table 3. Description the differenr retina datasets

Dataset Name	Pixel Size	Image Resolution	Image Format
DRIVE	524*584	24 bits per pixel resolution	.png
STARE	605 × 700	24 bits per pixel resolution	.png,.jpeg
CHASE	999*960	24 bits per pixel	.jpeg

V. RETINA VESSEL (RV) IMAGE SEGMENTATION AND METHODS

During segmentation or division process of the RV in two dimension pictures are mainly dependent on the local picture features, consisting the special features of the vascular sections. The two main methods are mainly measured for the detection of main vascular segments, related with various strategies for the classification of every pixel that is related to vessel or not. Generally, machine learning associated to retinal vessel segmentation are categorised as, supervised method(SM) and unsupervised methods (UM) [22].

A. Supervised Methods:

These methods is dependent on supervised-methods that are compulsory to have certain already defined marking data for selecting if the pixel is vessel or non vessel pixel, but there is not requirement of the already defined data in unsupervised methods. These methods are dependent on the rule that is learned by vessel segmentation approach and trained through manual process standard retinal pictures. The obtainability of the previously classified ground information in retinal pictures is essential for these methods. Generally, the supervised segmentation technique is dependent on previously classified information for segmentation.

(i) Perceptron and ANN Method

In this technique, the perceptron based technique is dependent on the prediction value by arranging the weigh to every feature whereas ANN is employed , when information are not linearly divisible. It consist large number of the units that is known as neurons which are linked and segmented into 3-layers namely input, hidden and output layer. Generally, the numerical weighs are allocated for regulating the required outcome for training method. Supervised learning method is based on model that depends on clear underlying possibility that predict information related to class instead of the classification. ANN has been mainly developed for the classification purpose. A method based AN N is proposed that depends on neural network(NN) with back propagation (BP) that utilised x-ray angiography for the identification of the blood vessels [23].The ground truth pictures is marked that manually utilised for training group to set weigh for neural networks. This method marked the pixels, vessel pixels that does not eliminate vascular system(network) of retinal pictures.

(ii) SVM (Support Vector Machine) Method

This method is overlapping block based supervised machine learning technique for the vessel segmentation. The main pixel of the block is characterised that depends on the area features and relation among the area and pixel features. The retinal pictures are segmented in to blocks and every block is explained by various features that are utilised as input vector for machine learning method [24]. Blood vessels are thin used pictures, where the thickness ranges from 1 to 6 pixels. On the basis of the block size , it is determined that every block contains vessel and non-vessel pixels. To classify the picture pixels, SVM is utilized as classifier for the classification purpose. SVM technique is built on the considered feature vector for the classification of the pixels into binary classes, vessels and non vessels. Generally, SVM is trained by matching blocks and 300 pixels of every class that is extracted randomly from training picture set and marked as vessel or non vessel that depends on ground truth pictures.

B. Unsupervised Method

This method is based on the classification process to recognise the intrinsic designs of retinal blood vessels for selecting the specified pixels interrelated to retina vessel or non vessel in pictures. In this method, the preparation information may not openly take part for planning of this method.

(i) Clustering Method

Clustering is the method of grouping the amount of the objects in to similar groups and it is measured as multiple objective optimization issue. Generally, fuzzy based retinal vessel segmentation process utilised the variation among the low and high pass filter of retinal pictures as input for fuzzy logic (FL) based method [25]. In fuzzy c mean clustering process, the division of the RV is done through various stages. In pre-processing phase, the green channel (GC) of resource picture was removed and improved by histogram equalisation. Afterwards, retina pictures are segmented into two layers as surface and smooth layer. Surface layer is directly inserted to the processing step. The features is achieved in the initial stage that are clustered by fuzzy c mean clustering algorithm. In addition, the estimated result is utilized as the starting rate of fuzzy c mean algorithm.

(ii) KNN Method

KNN is k nearest neighbour algorithm that is used for the organization and segmentation of vessels. The objects are classified through the distance from the neighbours with the group of class.The k number in the k nearest neighbour selects the amount of the neigbours that affects the classification. In this technique every, group of class is demonstrated by the position vectors in multiple dimension feature space. Generally, KNN works similarly with the arbitrary amount of the classes. Some of the applications of the KNN classifiers are systematically, simple, oriented and optimum in large sample limits that used local data which yields in adaptive way [26]. The features in the picture have nearest comparison that was collected into similar cluster, and features are computed that depends on contrast, illumination and classified through KNN classifier if the blood vessel is standard or non standard. This technique is computed and tested through dataset to achieve the accuracy and identify the blood vessels in picture

(iii) Hidden Markov Model (HMM) Method

This technique used a Markov model with 'hidden stages', where every stage consist the possibility distribution over the possible dissemination over the possible output that provides some data regarding series of the conditions [27]. HMM technique is based on various applications; reduced data involved in numerous vessel features, (ii) better performance rate of statistical features of HMM. Initially, the extraction of the vessel axis from gray scale three dimensional CT scan is done. Then, multiple features are computed for every voxel sequence. In final approach training depends on the vessel features by considering the probability rate of normal and fundus picture.

In table 4 , the existing outcomes of various datasets in retinal blood vessel are explained. In fig 6, the calculation result of Unsupervised and unsupervised machine learning parameters are elaborated. In addition, the percentage level on the basis of the performance metrices namely sensitivity, specificity and accuracy between the supervised and unsupervised methods are compared.

Table 4. Existing Result in Various Dataset (Retina Blood Vessel)

Author Name	Methods	SENS	SPEC	ACC
(Meng Li et al.,2017) [19]	**Supervised Method**	0.7680	0.9827	0.9630
	Unsupervised Method	0.7354	0.9789	0.9477

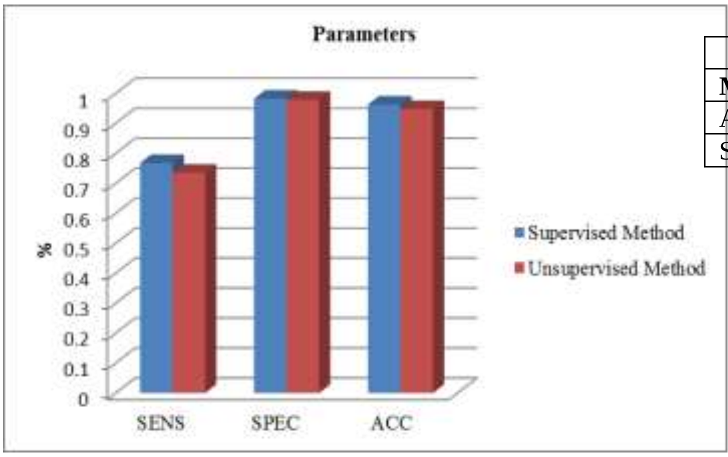


Fig 6. Evaluation: Supervised And Unsupervised Machine Leaning Parameter

In table 5, the experimental results of the unsupervised machine learning parameter taking accuracy level of different methods are described. The methods are KNN,HMM and FCM. The accuracy value of KNN is 94.4 %, HMM is 95.7 % and FCM is 96%.

Table 5. Unsupervised Techniques: Experiment Results

Unsupervised Techniques		
Method	**Accuracy Rate (%)**	**Citation**
KNN	94.4	[26]
HMM	95.7	[27]
FCM	96	[25]

In fig 7, accuracy percentage rate of the unsupervised machine learning parameters are demonstrated with different methods includes KNN, HMM, and FCM. In addition, the percentage level on the basis of the performance matrices namely accuracy rate between the supervised and unsupervised methods are compared.

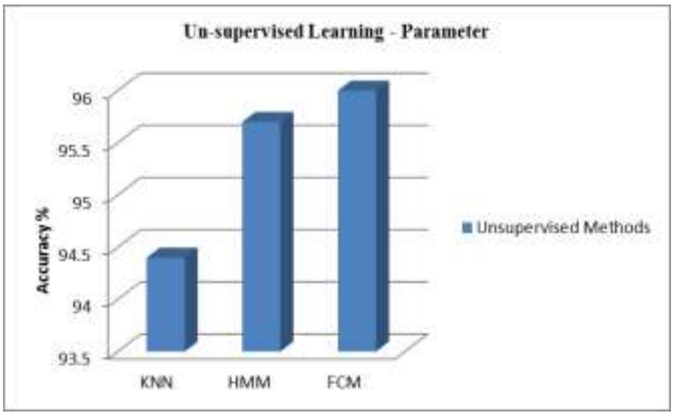


Fig 7. Several Un-Supervised Learning Parameters Evaluation

In table 6, the experimental results of the supervised machine learning parameter taking accuracy level of different methods are described. The methods are ANN and SVM. The accuracy rate of ANN is 94.9 and SVM is 95.3%. In fig 8, the graphical results are demonstrated with accuracy rate of two methods namely ANN and SVM . The comparative analysis of the two methods are done using accuracy metric

Table 6. Supervised Techniques: Experiment Results

Supervised Techniques		
Methods	**ACC**	**Citation**
ANN	94.9	[23]
SVM	95.3	[24]

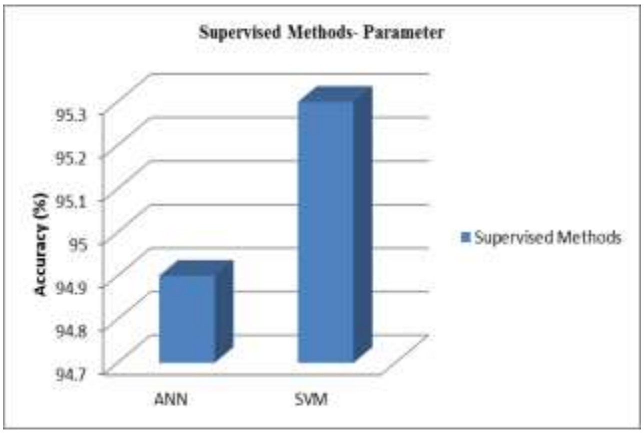


Fig 8. Several Supervised Learning Parameters Evaluation

VI. CONCLUSION

In conclusion, the inner portion of retina plays an essential part in the visualization of a person. The digitalized picture is captured by fundus camera that is beneficial to identify the deviations in RBV. Hence, in order to acquire the data of the BV through fundus retinal picture (FRP), a perfect vessel segmentation picture is mandatory. However, segmented blood vessels picture is more valuable to identify retinal diseases. Different automated methods are mainly utilised for retinal vessel segmentation that is mainly component of CAD (computer aided diagnose) method for retinal diseases. Generally, an automated vessel segmentation is more challenging approach due to presence of the illumination and noise. In this research, a comprehensive overview of the diabetic retinopathy along with datasets and types are explained. In addition, brief description of the fundus imaging and its methods are also given. Besides, the work flow of retinal blood vessel segmentation is also enlightened which includes image acquisition, pre-processing, optic papilla elimination and Fusion process. This research mainly described freely available datasets namely: DRIVE, STARE and CHASE; and also different machine learning methods. Various segmentation methods are based on the supervised and unsupervised methods. A complete review of the current supervised and unsupervised methods are considered that explained the viewpoint of every algorithm. It has been analysed the supervised methods performed better as compared to unsupervised techniques on the basis of the observation of the vessel segmentation. In this research, various retinal vessel segmentation techniques are ANN, clustering process, SVM, HMM method and KNN technique. In further work, it will implement a novel deep learning method to improve the performance parameters.

VII. REFERENCES

[1] Soomro, T. A., Afifi, A. J., Zheng, L., Soomro, S., Gao, J., Hellwich, O and Paul, M. (2019), " Deep learning models for retinal blood vessels segmentation: A review ,"IEEE Access, 7, 71696-71717.

[2] Soomro, S., Akram, F., Munir, A., Lee, C. H and Choi, K. N. (2017), " Segmentation of left and right ventricles in cardiac MRI using active contours,"Computational and mathematical methods in medicine, 2017.

[3] Mustafa, W. A., Abdul-Nasir, A. S. and Yazid, H. (2018), " Diabetic retinopathy (DR) on retinal image: a pilot study,"In Journal of Physics: Conference Series (Vol. 1019, No. 1, p. 012021). IOP Publishing.

[4] Kobrin Klein, B. E. (2007), " Overview of epidemiologic studies of diabetic retinopathy,"Ophthalmic epidemiology, 14(4), 179-183.

[5] Abràmoff, M. D., Garvin, M. K. and Sonka, M. (2010), "Retinal imaging and image analysis," IEEE reviews in biomedical engineering, 3, 169-208.

[6] Niemeijer, M., Abramoff, M. D. and van Ginneken, B. (2006), "Image structure clustering for image quality verification of color retina images in diabetic retinopathy screening.,"Medical image analysis, 10(6), 888-898.

[7] https://www.aoa.org/patients-and-public/eye-and-vision-problems/glossary-of-eye-and-vision-conditions/diabetic-retinopathy

[8] Singh, N., & Kaur, L. (2015), " A survey on blood vessel segmentation methods in retinal images," In 2015 International Conference on Electronic Design, Computer Networks & Automated Verification (EDCAV) (pp. 23-28). IEEE.

[9] Raja, D. S. S., Vasuki, S and Kumar, D. R. (2014), " Performance analysis of retinal image blood vessel segmentation," Advanced Computing, 5(2/3), 17.

[10] Sundaram, R., KS, R. and Jayaraman, P. (2019), " Extraction of blood vessels in fundus images of retina through hybrid segmentation approach," Mathematics, 7(2), 169.

[11] Saleh, M. D. and Eswaran, C. (2012), " An efficient algorithm for retinal blood vessel segmentation using h-maxima transform and multilevel thresholding, "Computer Methods in Biomechanics and Biomedical Engineering, 15(5), 517-525

[12] Elbalaoui, A., Fakir, M and MERBOUHA, A. (2018) , " Automatic Detection of Blood Vessel in Retinal Images using vesselness enhancement filter and Adaptive thresholding," In Ophthalmology: Breakthroughs in Research and Practice (pp. 18-33). IGI Global.

[13] Mustafa, W. A and Kader, M. M. M. A. (2018), " Automatic blood vessel detection on retinal image using hybrid combination techniques," Malaysian Appl. Biol, 47(2), 47-52.

[14] Yavuz, Z. and Köse, C. (2015), " Vessel segmentation in retinal images using multiscale image enhancement and clustering," In 2015 23nd Signal Processing and Communications Applications Conference (SIU) (pp. 581-584). IEEE.

[15] Wankhede, P. R and Khanchandani, K. B. (2015), " Retinal blood vessel segmentation using graph cut analysis," In 2015 International Conference on Industrial Instrumentation and Control (ICIC) (pp. 1429-1432). IEEE.

[16] Yao, Z., Zhang, Z and Xu, L. Q. (2016), " Convolutional neural network for retinal blood vessel segmentation," In 2016 9th international symposium on Computational intelligence and design (ISCID) (Vol. 1, pp. 406-409). IEEE.

[17] Ling, C., Lin, J., Huang, R and Yan, Z. (2019) " Blood Vessel Segmentation of Retina Image Using Markov Model in Wavelet Domain," In 2019 IEEE 13th International Conference on Anti-counterfeiting, Security, and Identification (ASID) (pp. 309-313). IEEE.

[18] Mankar, P. R. and Nimbarte, N. M. (2018), " Retinal Blood Vessel Segmentation using combination of top-hat and h-maxima methods," In 2018 IEEE International Students' Conference on Electrical, Electronics and Computer Science (SCEECS) (pp. 1-6). IEEE.

[19] Li, M., Ma, Z., Liu, C., Zhang, G. and Han, Z. (2017), "Robust retinal blood vessel segmentation based on reinforcement local descriptions," BioMed research international, 2017.

[20] Aastha, R. G, " A Review On Retinal Blood Vessel Segmentation Methodologies".

[21] Dash, J and Bhoi, N. (2017), " A thresholding based technique to extract retinal blood vessels from fundus images," Future Computing and Informatics Journal, 2(2), 103-109.

[22] Mendonca, A. M and Campilho, A. (2006), " Segmentation of retinal blood vessels by combining the detection of centerlines and morphological reconstruction.,"IEEE transactions on medical imaging, 25(9), 1200-1213.

[23] Akbar, S., Sharif, M., Akram, M. U., Saba, T., Mahmood, T., & Kolivand, M. (2019). Automated techniques for blood vessels segmentation through fundus retinal images: A review. Microscopy research and technique, 82(2), 153-170.

[24] Tuba, E., Mrkela, L., & Tuba, M. (2017), " Retinal blood vessel segmentation by support vector machine classification," In 2017 27th International Conference Radioelektronika (RADIOELEKTRONIKA) (pp. 1-6). IEEE.

[25] Xie, S and Nie, H. (2013), " Retinal vascular image segmentation using genetic algorithm Plus FCM clustering," In 2013 Third International Conference on Intelligent System Design and Engineering Applications (pp. 1225-1228). IEEE.

[26] Janney, B., Meera, G., Shankar, G. U., Divakaran, S., & Abraham, S. (2015). Detection and classification of exudates in retinal image using image processing techniques. Journal of Chemical and Pharmaceutical Sciences, 8, 541-546.

[27] Hassan, M., Amin, M., Murtza, I., Khan, A. and Chaudhry, A. (2017), " Robust Hidden Markov Model based intelligent blood vessel detection of fundus images," Computer methods and programs in biomedicine, 151, 193-201.

[28] Jiang, Y., Zhang, H., Tan, N. and Chen, L. (2019), " Automatic Retinal Blood Vessel Segmentation Based on Fully Convolutional Neural Networks," Symmetry, 11(9), 1112.