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Blood Vessel Segmentation Methods for Diabetic Retinopathy

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Abstract
Diabetes is a constantly recurring disease causedby failure of insulin production inthe body. Problems of Diabetes may leads to heart disorders and vascular disease like Diabetic Retinopathy (DR).The condition arises when blood vessels in the retina become swelled and the situations that leaks fluid which ultimately leads to vision loss/vision impairment. It is predominantly generates by the variations or changes in the retina vessels even though manual screening is available. The changes bring about due to diabetes mellitus follows significant micro-vasculature which in turn causes DR that eventually yields to complete vision loss. DR is also characterized by the retina deterioration with different types of lesions such as Micro aneurysms (MA), Hemorrhages, exudates, Hard Exudates, Soft Exudates, Cotton Wool Spots etc.. These lesion detection plays an outstanding part in the diagnosis of DR. Identification of structural changes in retina vessels are very composite and difficult , thus requires the help of Computer Aided Diagnosis (CAD) systems to qualify well organizeddiagnosis.Diabetic Macular Edema (DME) is aprogressive indication of DR and this may result in irreversible visual impairment.Here, segmentation ofblood vessels for detecting Diabetic Retinopathy isproposed. Blood vessel is one of the retinal features which can show the retina pathologies. It can be extracted from retinal image by image processing with following stages: pre-processing, segmentation, and post-processing. Segmentation process is the core process in blood vessel detection on retinal fundus image. In this process, blood vessel will be detected on eye retinal fundus image. Segmentation process withclassification techniquerequires the features extraction. It is necessary to performing an efficient segmentation process. The performance can be evaluated based on the accuracy and sensitivity obtained onsegmentation.

Keywords: *Retina, DiabeticRetinopathy, Diabetic Macular Edema, microaneurysms, exudates,hemorrages.*

1. INTRODUCTION

DR is a micro vascular impediment of diabetes, whichis asymptomatic in the inceptive stages. The unconfined increase in diabetes shows that the illness has become a provocation for health care zone also. The result of a present- day survey be visible an exponential rise of diabetic patients from 153 to 347 million. Diabetes is considered as the source of many fitness related issues.Thekeyfactorsthatcausesdue to diabetes are micro vascular variations which

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can lead the stage known as DR, renal issues and heart ailments also. DR can also be marked by the existence of dissimilar lesions well known as Micro aneurysms (MAs), Hemorrhages (HEMs) lesions and Exudates(EXs)[1].

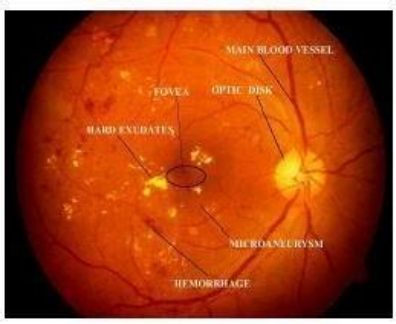

Fig 1.1 Illustration of various features on a typical retinopathic image

Enlargement in macula of eye known about asMacular Edema, is an obstacle which can gradually bring down the ability of perception. DME well known as Diabetic Macular Edema is a excessive prospect which can cause rectifiable vision loss. An efficient yet effective solution for this problem is to analyze and detect the structural changes on the retinal blood vessel of fundusimages. Premature symptoms of the disease are indicated by retinal blood vessel's attributes like diameter, length, angle, and tortuosity [2]–[5]. Even though detection of a minor sign of the same is crucial as it may appear without any external indications [6]. During inspection of retina, this calls an emergency treatment from BP (Blood Pressure) regulation to lasertreatment.

Diabetes triggers the damage of retina because of lack of insulin in body or inability of the body cells to respond to insulin. Retinal blood vessels entering the retina from the optic disc are damaged which result in vision impairment. Asmentioned earlier, initial stage shows no change in vision, but theuncontrolledwayoftreatingdiabetesmayleadt ototalloss of vision. In this fast paced life, the increasein diabetes may take up to 642 million in 2040 and it is found that DR cancause loss of sight in 1.8 million from 37 million people. Diabetic Retinopathy is fall under two categories known as Non Proliferative and Proliferative Diabetic Retinopathy,among these primary stages known as Non Proliferative Diabetic Retinopathy (NPDR) stipulate the signs of Micro- aneurysms, Exudates and Haemorrhages. The advanced stage of Diabetic Retinopathy known as Proliferative Diabetic Retinopathy (PDR) can be denoted by the imprudent widening of extensive new blood vessels in the retina [7].

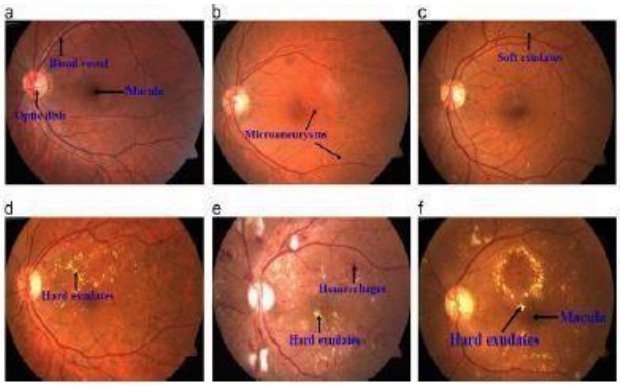

Fig 1.2 Varied features of the diabetic retinopathy image

A quick explanation concerning key DR attributes are given below[1]:

Micro aneurysms (MA):

Micro aneurysms (MAs) are regarded as the most ancient sign of retinal injury. The unexpected absorptive nature of retinal blood vessels outcomes causes the emergence of MAs. Conventionally, it is small red spots, round in shape and the dimensionality lies between 20µm to 200µm.

Hard Exudates (HE):

Hard exudates (HEs) are lipoproteins discharge out of the vessels. It considers unevenly scattered small white or yellowish-white deposits. These lesions are usually structured in the form of circular rings in retinal-outer layer.

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Soft exudates or Cotton Wood Spots (CWS):
Results due to arterial occlusion.The lessened blood flow results into a state known as Ischemia that cautiously impacts the axoplasmic flow which assemble axoplasmic scrap. Such gathering (assembling) can be seen as white deposits in the Retinal Nerve Fiber Layer (RNFL), often known as CWS.

Hemorrhages (HEM)}:
Hemorrhages are designated as red spots with fluctuating density varying margin. It is found in the range of 125µm. Hemorrhages are widely categorized into two types as Flame and Dot-blot hemorrhages (DBH), by which flame type emanate from pre-capillary arterioles and become visible atthe nerve fibers. On the other hand, DBHs are round structures which appear at divergent levels of retina and take place at the venous end of capillaries.

Neo-vascularization (NV):
Neo-vascularization can be expressed or identified as the come out of the emergence of new blood vessels on the interior side of retina frequently. NV repeatedly lose blood to vitreous cavity that can also disgrace visioncapability.

Macular Edema (ME):
A bulge part of retina that results due to the porous nature of various retinal capillaries.ME can roots leakage of fluid as well as further solutes throughout the macula that slowly exerts influence on the vision capability.

A. Types of DiabeticRetinopathy

Predominantly, DR is categorized into two large categories as Non proliferative DR (NPDR) and Proliferative DR (PDR) asstated earlier[1].

There are three subordinate classes for NPDR specifically mild, moderate and severe NPDRs.

Mild NPDR can be specified with the existence of at just one MA accompanied or unaccompanied by any HE, HEM or CWS. About 40 percent of the diabetic patients have mild- NPDR indications. Moderate NPDR is the one which features a number of MAs and HEMs. A special case considered in this NPDR stage is the likeliness to develop PDR within one year or not. Severe NPDR can be identified by retinal quadrants (ISNR).
Advanced phase of retinopathy known as PDR is the stage of unusual extension of blood vessels. Due to the existence of brittle walls, it raises the chance of possibility of leakage. Such leaked blood can have an effect on the vision capacity due to collision with vitreous gel[1].

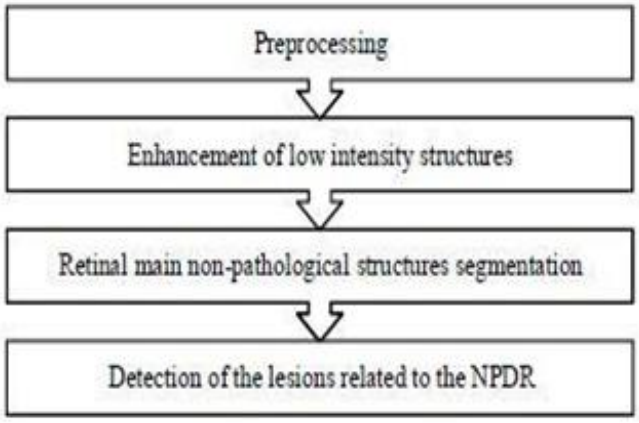

Fig 1.3 Outline method for the detection of the lesions related to the NPDR Different class of Diabetic Retinopathy and its extremity are presented in figure 1.4 given below.

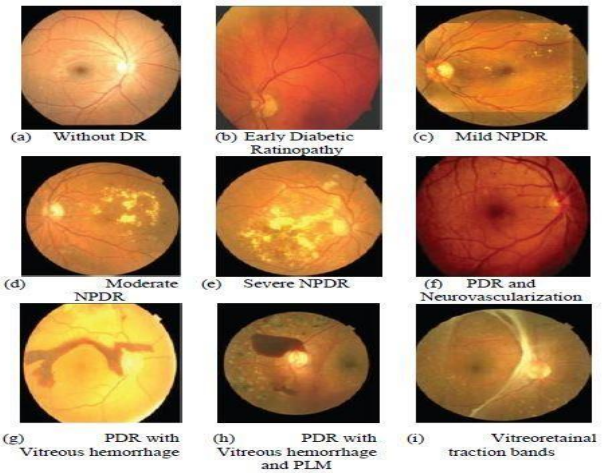

Fig 1.4 Classification of diabetic retinopathy

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The tone of fundus can differ. This can be different in shades like blue, yellow, green, orange and red. Yet human fundus is at most in red colour. The reproduce of fundus images can be done either by two techniques called fundus photography or by using fluorescein angiography. Fundus photography is minimally invasive proficiency but at the same time, Fluorescein angiography is an invasive technique found on taking place within a fluorescent substance, consequently process images with intensify disparity than usual [8].
Some of the image processing techniques used by the researchers in order to diagnose eye related ailments are Image Enhancement, Registration, Fusion, Segmentation, Feature Extraction, Morphology, and Classification. The explanation given by they are described in a very brief manner, are as follows [9]:

Image registration:
Image registration is used to detect the changes in medical images. Here, the different images captured from different angles are aligned in a one coordinate system in order to get registered without any failure.

Image fusion:
Image fusion is used to unite various information from different images into one.

Segmentation:
Segmentation is used to divide or subdivides an image into multiple regions on the basis of colour, intensity, and objects.

Image Classification:
Image Classification is used to label the group of pixels on the basis of grey values or other parameters.

Image analysis:
Image analysis is used to make the image contents to understand in an very easy way.Observing DR lesions are accomplished by supervised learning methods demands the training of classifiers utilizing experts; they labeled the target at pixel level. Following procedure is to take out attributes from each pixel. Ultimately the isolated pixels are merged into objects [10].

B. *SignsandSymptomsofDiabeticRetinopathy*

Signs and symptoms of diabetic retinopathy may include [11]:

1. Blurredvision
2. The impairment of colourvision
3. Floaters,ortransparentandcolourlessspotsand darkstrings that float in the patient's field ofvision
4. Patchesor streaksthatblock theperson'svision
5. Poor night vision
6. Suddenandtotallossofvision

I. METHODS FORBLOOD VESSEL SEGMENTATION

This section considers some processes that are used for blood vessel segmentation for determine DR. The structural changes happens in vessels of eye is vital for the judgment of disease diabetic retinopathy. But the physical identification of blood vessels is a time utilizing process and the segmenting precision fully depends on the researcher’s involvement [12].

An analysis of image enhancement methods for diagnosing and detecting DR was proposed by sharad et al. in [13].

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Fig 2.1: Proposed blood vessel extraction method [14]

Kuri et al. in [14] prefers a technique for removal of blood vessel by operating with a high efficiency filter called Gabor which shows excessive positive rate meanwhile lessens false observation [14]. The method proposed by kuri et al. is shown in figure 2.1. The gain that acquired from the above diagnosis is utilized for recognizing Diabetic Retinopathy (DR). In [14] preliminary processing is practically used to remove noises in fundus images. Since retinal images are usually difficult to detect in reduced disparity, the green channel of retina are used as a part of contrast enhancement purpose. CLAHE, well known as Contrast Limited AdaptiveHistogram Equalization is used for enhance the dissimilarity of green channel. For detecting the blood vessels Gabor filters are used. Filters of these kind, analyses any specific frequency content in the image in specific directions. The equation of the proposed filter can be expressedas,

$$g_\theta(x,y) = \exp(-1/2\{\frac{x_\theta^2}{\sigma_x} + \frac{y_{\theta\gamma}^2}{\sigma y}\})$$

Where

σ_x=Standard deviation

σ_y= Standard deviation of Gaussian (controls orientation)

f= Pass band central frequency

θ = filter orientation

The optimization of Gabor filter in [14] is shown below,

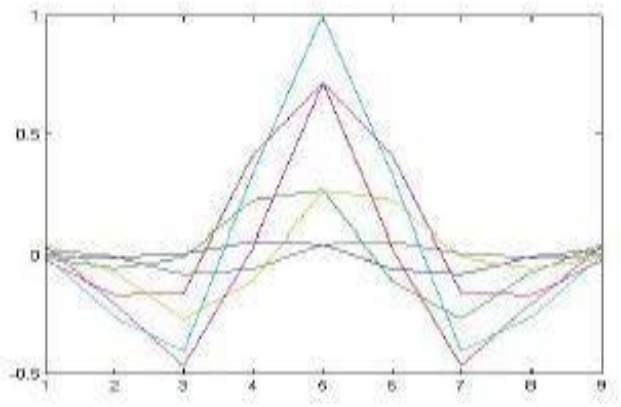

Fig 2.2 Optimization of Gabor filter

The use of a 3*3 filter called median filter is used here to reduce the salt & pepper noise, while the usage of length filter at the last stage removes the pixels which are left isolated by using the connectivity of binary image [14].

Di Wu et al. in [15] proposed another scheme for large as well as small blood vessel detection. This scheme consists ofthree functions namely adaptive contrast enhancement and extraction of blood vessels & tracing. The enhancement of blood vessels can be obtained from Adaptive Histogram Equalization (AHE). Small vessel extraction can be achieved by filter response standard deviation on different orientations. Tracingofvascular networkcomposedofthreemainfunctions called forward detection, backward verification and bifurcation detection.Automatic detection of blood vessels helps in the measurement as well as the analysis of morphological changes. Detection of large blood vessels is mostly preferred in noise-free images, but the detection process is much more difficult[15].

Blood vessel detection schemes are divided into

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two categories as pixel classification and vessel tracing. The ultimate aim of pixel classification schemes are to decide whether a pixel be held by the blood vessel or not, on the basis of above outcomes of image features of the pixel under analysis. Tracing emanate from initial vessel point and then find the vasculature by discover the vessel boundaries and their directions.

In addition to the conventional illumination and adaptive equalization schemes, Di Wu et al. follow a Gabor-based filtering method which is very much effective for the enhancement of small blood vessels. The tracing algorithm uses different types of feature information.

Tracing:

The main objective of blood vessel tracing is to generate a final vascular map on the basis of the properties of blood vessels. By using the feature maps, tracing originates frompreselected initial points, at which primary estimations (widths and directions) of vessels will be made. Vascular network forms a segment by segment fashion on each branch, by assuming that each segment has a fixed width and direction [15].

Most of the retinal illness in [16] are specified by deviations in vessels of eye. The retinal formation comprises of arteries and veins. The principal

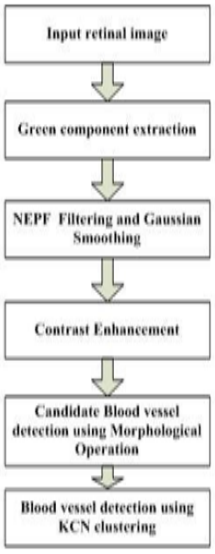

Fig 2.4 Flow chart [17]

indication for DR is the asymmetrically unfurl veins, which conducts very low proportion of mean diameter of arteries to veins, known as AVR. A proceed towards the separation of arteries and veins using segmentation and neural classification method is considered here. In this approach, eye vessels are partitioned using 2D matched filters. Finally, the acquired extractions (features) will be fed as an input to MLP, known as Multi-Layer Perceptron with the target to differentiate the vessels into arteries andveins.

Retinal vessel division methods can be categorised into two groups as pixel processing-based methods and tracking methods. Matched filtering techniques are commonly used for global as well as local thresholding approaches. The vessels are progressively get segmented in a region growing procedure [16].

Illustration of pre-processing stages in [16] is shown in the figure given below.

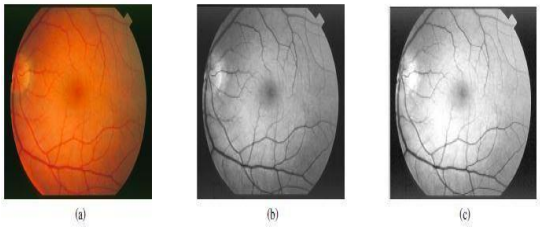

Fig 2.3Images of the preliminary process: Original (a) , Green channel (b), Enhanced image (c).

Mehrotra et al. prefers a method of blood vessel detection in [17]. In this method, morphological operators together with KCN clustering are used. Top-hat and bottom-hat transformation is applied in the morphological operation. Diabetic Retinopathy is concerned initially with the abnormalities occurring in blood vessels activated by uncontrolled shooting of glucose level in the body.

The various components in human retina such as macula, fovea, optic disc and blood vessels are shown in figure below [17].

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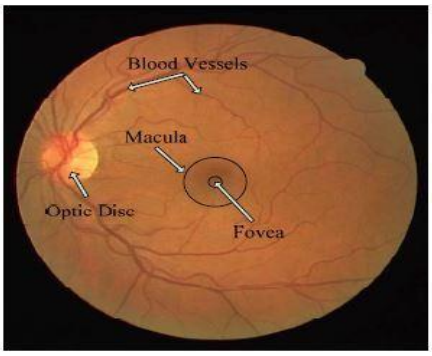

Fig 2.4 Main components of retina

For the automatic detection of DR, evaluation of retinal blood vessels is essential. Therefore, Gabor filters with different parameter scales are required for its precise visualization [17].

NEPF, well known as Novel Edge Preserving Filter is used for detach noise especially impulse noise while Gaussian smoothing is used to unfasten the Gaussian noise. The operator in Gaussian operation called Gaussian Smoothing Operator carry out average of adjacent pixels, establishes on the distribution and abolish the effect of noise.

The unbalanced illumination in some area of images roots non uniform illumination in unrelated areas of the same image. To avoid this problem, enhancement in contrast techniques are applied to obtain undeviating illumination throughout the image. This may improves the contrast of blood vessels too. The two transformation techniques (morphological operators) highlight the candidate blood vessels. Extracting the details of small elements helps to enhance the minute vessels.

Detection of blood vessel using KCN:

It is the simplest neural network, in the sense that it has no hidden layer and activation function. Network comprises twolayers called input and output layers. KCN method considers the one closest to input by means of Euclidean distance, can be assigned as as winner neuron which weights with its predefined neighbours are strictly correct with the help of a learning rule. The last map is formed by clustering the differences into two clusters using Kohonen Clustering Network (KCN).

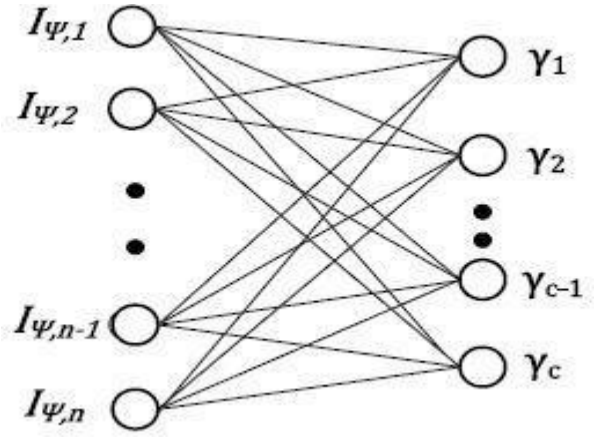

Fig 2.5 Architecture of KCN

The performance of [17] was measured using the parameters stated below:

1. True Positive (TP): The proportion of actual positives (here the blood vessel pixels) that are precisely identified assuch.
2. True Negative (TN): The proportion of actual positives(non
- blood vessel) precisely identified as non-vessel pixels.
3. False Negative (FN): The vessel pixels identified as non- bloodvessel.
4. False Positive (FP): The vessel pixels identified as blood vessel.

The four above mentioned measures are normally preferred to compute the accuracy. Apart from the four mentioned parameters, sensitivity and specificity are the two important parameters and it can be defined as the percentage of actual positives that are found, and exact precision is computed by the proportion of the integers of correctly classified pixels to the total integers of pixels in the image.

Sensitivity= (TP} +FN)/TP

Accuracy=FP}/ (TN} +FP})

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Thanapong et al. [18] prefers a method for extraction rely on fuzzy C-median clustering algorithm. The opted method uses matched filtering, fuzzy c-median (FCMED) clustering and label filtering techniques for processing

The algorithm composed of three steps. Green channel is preferred here also, then this green channel together with the help of a MFR known as Matched Filter Response generation. Next a Fuzzy median is used to separate the vessel segments and background. At last, a filtering technique is used to remove unwanted pixels.

Matched Filtering:

In matched filtering, profile intensity is the section of blood vessels which can be calculates by Gaussian curve [18].

The expression of kernel can be expressed as,

$$f(x,y) = -\exp\left(-\frac{x^2}{2\sigma^2}\right)$$

FCMED Clustering:

In [17], the proper working of this scheme isclearly mentioned. To define this, first consider a setof N vectors X= , ,. } this isto be clustered into ‘c’ groups ofsame data. Eachin, where k = 1, 2, N isa feature vector consisting of ‘p’ real valued measurements which explains the features represented by The features can be length, width,
colour etc..

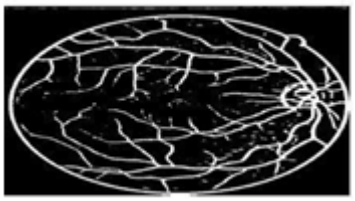

Fig 2.6 Result after FCMED clustering

In [19] a vessel segmentation methodology is proposed. In this method, authors make use of 2D Gabor wavelet method followed by adaptive thresholdingstrategy. An assure technique of extracting the blood vessels and method for segmentation would be helpful for the DR detection[19].

A segmentation strategy in [20] develops analgorithm namely ‘star networked pixel tracking’ which contains the common steps such as preliminary processing, vessel segmentation, pixel tracking and the final processing steps [20].

The concept of the tracking algorithm is proposed by Helen [20]. This method is used to nullify the noises in a vessel like fashion. Image enhancement steps include local enhancement, which is applied to thin vessels. Morphological operations are mainly focusing to strengthening the intensity levels of small and minute vessels. This makes a normalized retinal image to create binary image. Now the artifacts so are cleared in the post-processing stage.

Dhara et al. proposed various feature combination to separate the blood vessel pixels from background in [21]. Theproportion of RGB colours is usually given in the following manner:-

Y=0.299R+0.587G+0.114B

Changes that happened in the vascular pattern shows the effects diabetes [22].

Mithunet al.[23] proposed another novel methodto recognize optic disc and blood vessels. Here, some basic techniques such as edge detection, binary thresholdingand morphological operation are performed. Preliminary processing is applied by using filtering technique. Edge detection strategy is followed for feature extraction. Usually Optic Disc (OD) is the brightest part of retinalimage.

Detection based on Edge and line operators are also proposed by Chin- Chen Chang in [24]. Later in the year 2007, two researchers named Ricci and Perfett introduced an efficient

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segmentation method based only on line operator. The concept of RBVSLE is also mentioned here, generates a map called edge map by which it specifies the seed map growth by using the aid of canny edge detector.

Akram et al. presents a method for detecting the stage called neovascularisation [25]. Since image usually contains various pixels which are not essential for further processing.

Lazar et al. describes another fast, simple yet accurate method for blood vessel division [26]. The method recognisesthe vessels by focussingon various orientations by allotting a vector to every pixel on Region of Interest (ROI). Each elementofthisparticularvectorpointouttheheight atagiven direction and computes the height from the corresponding profiles.

Staal et al. gives a two-dimensional segmentation strategy. This is based on image ridge extraction. These are used to make primitives which divides into several small patches to the more nearest one. Local coordinates for its corresponding patch are holed [27].

Curvelet transform for the vessel extraction may also advances in this field. This contains four stages as contrast enhancement, filtering, edge extraction and finally the length filtering. All these concentrates on the curvelet domain [28].

II. CONCLUSION

One of the alarming health issues caused due to the improper functioning of diabetes is Diabetic Retinopathy (DR). Over the years, many more health related consequences caused have beenwitnessedduetodiabetes.Therearenumerou s scenarios that identifying DR with more complex features isnot feasible.Asameansofsolutiontothisproblem,cert ainrobust computer aided diagnosis (CAD) systems are developed with the aim of an earlier DR detection. Automatic DRdetectionand its diagnosis generally make use of retinal fundus images asinputandthefollowingprocessingtechniquesid entifiesthe abnormalities contained in it based on the key DR features such as MAs, HEMs, Exudates, CWS etc.. andcan diagnose its severity. An automatic DR detection system comprises of some sequential phases like preliminary-processing, segmentation, feature extraction and finally the classification,wherethefirststepismeantforimpro vesthequalityoffundus image. Segmentation performs by distinguishing the ROIfrom background, which is followed by segmented ROI extraction forclassifications.

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