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Denoising the Underwater Images by using Adaptive Filters

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ABSTRACT

The Sound Navigation And Ranging and synthetic aperture radar images are perturbed by the multiplicative noise called speckle noise . The presence of speckle noise leads to incorrect analysis and has to be handled carefully. Images have a strong variation from one pixel to another which reduces the efficiency of the algorithms for detection and classification. In this paper, the most well-known filters are analyzed by using underwater images. It is shown that they are based on a test related to the local coefficient of variation of the observed image, which describes the scene heterogeneity. Linear noise removing models can remove noise but are not able to preserve edges of the images in an efficient manner . On the other hand, Non-linear models can handle edges in a much better way than linear models. It is found that the linear filters and nonlinear filters can remove noise from small area objects and homogeneous areas but not in heterogeneous areas. Adaptive filters are used to remove noise not only from homogeneous area but also from heterogeneous areas. This paper presents an optimum filter by using locally estimated parameter values to provide minimum mean square error in order to smoothen the sonar images. It is also shown that the optimum filter is computationally efficient. The performance of this adaptive filter is compared (qualitatively) with other filters and found that the complexity of the frost filter is reduced.

Keywords: Speckle noise, adaptive filter, mean square error, homogeneous areas and heterogeneous areas.

1 Introduction

Image restoration is an area that also deals with improving the appearance of an image. However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation. The field of image restoration is concerned with the reconstruction or estimation of the uncorrupted image from a blurred and noisy one .Image restoration is done by restoration filters. Restoration filters are used to reduce the degradations which occur due to sensor noise, blur, camera misfocus, relative object-camera motion and random atmospheric turbulence.

Restoration refers to removal or minimization of known degradations in an image. This includes de-blurring of images degraded by the limitations of a sensor or its environment, noise filtering and correction of geometric distortion or non-linearties due to sensors fundamental result in filtering theory. Generally speaking there are two techniques of removing/reducing speckle noise[1], i.e., multi-look process and spatial filtering[12]. Multi-look process is used at the data acquisition stage

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while spatial filtering is used after the data is stored. No matter which method is used to reduce/remove the speckle noise, they should preserve radiometric information, edge information and last but not least, spatial resolution. These are the conditions that any speckle noise reduction technique should meet. Spatial filters are mainly categorized into two general groups ,i.e., non-adaptive and adaptive filters. Non-adaptive filters are those which neglect the local properties of the terrain backscatter or nature of sensor. Non adaptive filters are classified as linear and non linear filters. However, adaptive filters accommodate the change in the local properties of the terrain backscatter or the nature of sensor. Linear filters are averaging(mean)filter and wiener filter[9]. Nonlinear filters are median filter[8][12][2].

2 The Existing Filtering Methods

2.1 Weiner Filter

Wiener Filter[9]is to filter out noise that has corrupted a signal. It is based on a statistical approach. Typical filters are designed for a desired frequency response. The Wiener filter approaches filtering from a different angle. One is assumed to have knowledge of the spectral properties of the original signal and the noise, and one seeks the LTI filter whose output would come as close to the original signal as possible.

The Wiener filter is:

$$G(u,v)=\frac{H*(u,v)Ps(u,v)}{[H(u,v)]^2Ps(u,v)+Pn(u,v)} \quad (1)$$

Dividing through by P_s makes its behaviour easier to explain:

$$G(u,v)=\frac{H*(u,v)}{[H(u,v)]^2+\frac{Pn(u,v)}{Ps(u,v)}} \quad (2)$$

where

H(u,v) = Degradation function and u,v are picture elements(pixels) of an image.

H*(u,v) = Complex conjugate of degradation function

$P_n(u,v)$ = Power Spectral Density of Noise

$P_s(u,v)$= Power Spectral Density of un-degraded image. The term P_n /P_s can be interpreted as the reciprocal of the signal to noise ratio.

2.2 Averaging Filter:

Averaging Filter: Average (or mean) filtering is a method of 'smoothing' images by reducing the amount of intensity variation between neighbouring pixels. The average filter works by moving through the image pixel by pixel, replacing each value with the average value of neighbouring pixels, including itself. We can use linear filtering to remove certain types of noise. The Mean Filter is a linear filter which uses a mask over each pixel in the signal. Each of the components of the pixels which fall under the mask are averaged together to form a single pixel. This filter is also called as average filter. The Mean Filter is poor in edge preserving.

$$\hat{f}(x,y) =\frac{1}{MN}\sum_{(s,t)\in S_{xy}} g(s,t) \quad (3)$$

2.3 Median Filter:

Median filtering is a nonlinear method used to remove noise from images. It is widely used as it is very effective at removing noise while preserving edges. It is particularly effective at removing 'salt and pepper' type noise. The median filter works by moving through the image pixel by pixel, replacing each value with the median value of neighbouring pixels. The pattern of neighbours is called the "window", which slides, pixel by pixel over the entire image. The median is calculated by first sorting all the pixel values from the window into numerical order, and then replacing the pixel being considered with the middle (median) pixel value.

$$\hat{f}(x,y) = \underset{(s,t) \in S_{xy}}{\text{median}} \{g(s,t)\} \tag{4}$$

2.4 Adaptive filters:

An adaptive filter is a system with a linear filter that has a transfer function controlled by variable parameters and a means to adjust those parameters according to an optimization algorithm. An adaptive filter iteratively adjusts its parameters during scanning the image to match the image generating mechanism. Adaptive Filters reduces speckle noise in homogeneous areas, preserves the texture and high frequency information in heterogeneous areas[12].Adaptive filters take into account local image statistics while carrying out the filtration process, and hence they are able to remove the noise while preserving the texture. The different types of adaptive filters are lee Filter[3], Kuan Filter[5][6], Frost Filter[4][13], MAP(Maximum A Posteriori)[10],Modified Lee[13], Modified Frost filters[13] and SRAD(Speckle reducing anisotropic diffusion)[14] Filter. The Lee and Kuan filters have the same formation, although the signal model assumptions and the derivatives are different. The Frost filter also strikes a balance between averaging and the all pass filter. In this case, the balance is achieved by forming an exponentially shaped filter kernel that can vary from a basic average filter to an identity filter on a point wise adaptive basis. Compared to all the adaptive filters, frost filter gives best results. It reduces the noise not only in homogeneous areas but also in heterogeneous areas. This results in computational complexity. The computational complexity is reduced.

2.5 Performance parameters for comparative analysis

2.5.1 Mean Square Error

Mean Square Error is the ratio of the square of difference between the input and output

image to the size of the image.

$$\text{MSE}=\frac{1}{MN}\sum_1^M \sum_1^N \big(f1(i,j) - f2(i,j)\big)^2 \tag{5}$$

Here f1, f2 are the input and output images respectively. M and N are the sizes of the images. The MSE should be less, which means that the pixel intensity of the input and output image should be as close as possible.

2.5.2 Peak Signal to Noise ratio (PSNR)

Peak Signal to Noise ratio (PSNR) is the logarithmic value of the ratio of size of the image and the mean square error of the image.

$$\text{PSNR}= 10 \log \frac{255\text{^}2}{MSE} \tag{6}$$

PSNR should be as large as possible which means that the content of signal in the output is large and the noise is less.

3 Adaptive Filters

Contrary to the standard filters, the adaptive filters take local image information into consideration while carrying out the filtration process. Adaptive filters can reduce speckle noise in homogeneous areas while preserving texture and high frequency information in heterogeneous areas. The design of each speckle suppression filter is based on different criteria and parameters and the performance of each speckle filter may vary from one sonar to another; therefore, no generic de-speckling algorithm exists [09]. Consequently, selection of the right de-speckling filter for a specific environment and sensor is a difficult task. Frost [13] filter produces the best results, but as with all the speckle filters, it was not intended for real time processing and is the most computationally complex. The proposed algorithm reduces computational complexity which in turn reduces the elapsed time. The Frost filter reduces speckle noise and preserves important image features at the edges with an exponentially damped circularly symmetric filter that uses local statistics within individual filter windows.

A brief description of adaptive filters is given below

3.1 Lee Filter

Lee approximated the multiplicative noise model with a linear one, followed by applying a Minimum Mean Square Error (MMSE) criterion [13]. Then an adaptive filter was formulated as

$$R(x,y) = Ib\,(x,y)(1-W(x,y))+W(x,y)\,I(x,y) \tag{7}$$

where I is the acquired image, Ib is the average of an acquired image in a filter window, and W is a weighting function given by

$$W(x,y) = 1- \{C_u^2/\,C_I^2(x,y)\} \tag{8}$$

$C_u = \sigma_u/\,ub$, $C_I(x,y) = \sigma_I\,(x,y)/\,Ib(x,y)$, are the variation coefficients of the noise and the acquired image, respectively. The σ_u and ubar is noise standard deviation and mean respectively. $\sigma_I\,(x,y)$ and Ibar(x,y) is the image standard deviation and mean in the area around (x,y).

3.2 Frost Filter

This filter is different from Lee filter. It estimates the observed scene by convolution of the acquired image with the impulse response of the imaging system. The imaging system impulse response is obtained by using the minimal mean square error (MMSE) criterion. Then the resulting filtering process can be defined by a convolution of the acquired image with the filter kernel.

Weighting Function

$$W(x,y)=K_1 e^{-K}d\ {}^{C}I^{(x,y)*sqrt(x2+y2)} \tag{9}$$

C_{si}–standard speckle index(measure of speckle reduction)

C_I–varied standard speckle index

K_d --damping Factor-defines the extent of smoothing-default value 1

$$C_{si}= \frac{\mu}{\sigma} \tag{10}$$

Filtering Formula:

$$R=I*\ W \tag{11}$$

4 A New Optimized Filter

4.1 Modified Frost filter

The frost filter increases the computational complexity. This is due to more number of computations. From equation 2.2.1

- Computational complexity is due to following operations involved in calculating in weighting function
  - 2 squares, square root, 3 multipliers, exponent, multiplier
- Square root replaced by x+y
- Exponent function replaced by using taylors series

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots, \qquad -\infty < x < \infty$$

Hence it takes more elapsed time for execution. This elapsed time is reduced by modifying the window function as given below.

$$W(x,y)=K_l[1- K_d C_l(x,y)(X+Y)] \tag{12}$$

4.2 This reduces the number of computations and hence computational complexity is reduced.

5 Experiments and Analysis

The experiments are performed on following underwater images:

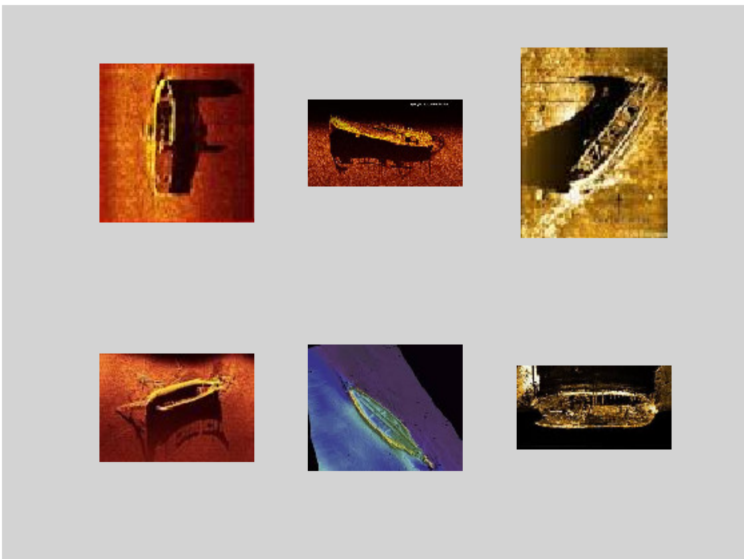

Figure 1: Underwater images

Table 2. Comparison of filters with respect to mse and psnr.

Filter	MSE	PSNR
Linear filter-mean filter or averaging filter	7502	9.1
Non Linear filter-median filter	201	25
Non Linear Filter-Wiener Filter	128	27
Adaptive Filter- Lee Filter	306.6	23.2
Adaptive Filter- Frost Filter	165.5	24.7

From the Table II, wiener filter has the least mean square error. It is observed that the linear filters and nonlinear filters can remove noise from small area objects and homogeneous areas but not in heterogeneous areas. Adaptive filters are used to remove noise not only from homogeneous area but also from heterogeneous.

Table.3 Comparison of Frost filter and proposed filter results.

Image	Frost Filter-MSE	Frost Filter-Elapsed time	Optimized Filter: MSE	Optimized Fiter: Elapsed time
Image 1	165	2.35 secs	165	0.205 secs
Image 2	221	109 secs	221	3.99 secs
Image 3	539	2.18 secs	539	0.255 secs
Image 4	161	2.7 secs	167	0.27 secs
Image 5	35	20 secs	35	1.5secs
Image 6	241	24 secs	241	1.509 secs

From the Table III, it is observed that mean square error and power signal to noise ratio for two images using frost filter. The complexity of frost filter is due to more number of computations which is reduced modifying the frost filter. This reduces the number of computations hence the elapsed time for execution is reduced.

Original gray image and Frost Filtered output

- Elapsed time is 0.462370 seconds.
- mse1 = 165.5576

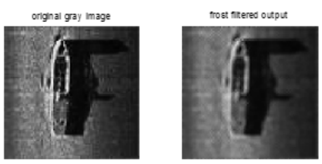

Figure 2: original image and frost filtered image

Original gray image and frost filtered output after reducing the computational complexity

- Elapsed time is 0.127528 seconds.
- mse1 = 165.5576

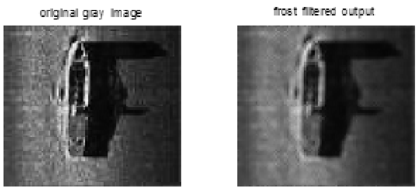

Figure 3: original image and optimum filtered image

6 Conclusion

In this work all the classical filters like Lee, Frost, Kuan, GMAP filters, SRAD, linear and nonlinear filters were compared with MSE and PSNR for identifying a best filter. Frost filter was proved to be best but it was found to be computationally complex. Here frost filter is designed with less complexity and reduced elapsed time. The existing filters do not enhance edges-they only inhibit smoothing near edges.

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Stroke Prognosis through Retinal Image Analysis

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ABSTRACT

Many eye diseases as well as systemic diseases usually used to manifest in the retina. The innovations in the field of retinal imaging have paved the way to the development of tools for assisting physicians in stroke prognosis. Stroke is one of the leading causes of adult disability in most of the developing countries. Diagnosis of stroke during the initial stage is crucial for timely prevention and cure. Retinal imaging provides a non invasive technique of predicting the possibility of stroke. This research work focuses on the prediction of retinal ischemia from retinal fundus images and thereby predicting the occurance of stroke. Preprocessing of retinal images is done by retinex processing and morphological operations are done to remove noisy background. Branching points are detected and various features like major axis length, mean diameter, orientation, eccentricity, fractal dimension and tortuosity for the branching blood vessels are computed. This has been compared for various diseases like diabetic retinopathy, hypertensive retinopathy and retinal ischemia against a set of healthy retinal images. Classification has been implemented by Artificial Neural Networks which gives an accuracy of 89 % and the results proved to be promising.

Keywords: Stroke, prognosis, retinal image, retinex, retinal ischemia

1 Introduction

Stroke is a form of cardiovascular disease affecting the blood supply to the brain. It remains as a leading cause of disability and death for people of all races and ethnicities [1]. Stroke is a physical condition that occurs due to insufficient supply of blood to the brain cells. This damages the brain cells ultimately leading to their death. A clot in the blood vessel or a blood vessel rupture can interrupt the blood supply to brain. Stroke can be subdivided into two types : ischemic and hemorrhagic. Ischemic stroke accounts for almost 85% of the cases. It occurs as a result of a block within a blood vessel supplying blood to the brain. Hemorrhagic stroke occurs when a weakened blood vessel ruptures. When an obstruction occurs within a blood vessel supplying blood to brain, the vessels carrying blood to eye will also be affected during the initial stages. This is termed as Retinal ischemia. Persons suffering from Retinal ischemia are more prone to stroke.

The retina can be viewed and analyzed using non-invasive in vivo functional techniques. Retinal imaging and image analysis have developed rapidly over the past ten years, and image analysis plays an important role in the care of patients with retinal diseases, as well as diseases that manifest in the retina. Retinal imaging allows diagnosis of various eye diseases as well as the prognosis of other complications of diabetes, hypertension and cardiovascular diseases like stroke. The retina is a layered tissue lining the inner part of eye that enables the conversion of incoming light into a neural signal

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that is appropriate for further processing in the brain. It is therefore an extension of human brain. The ability to image the retina and develop methods for analyzing the images is of great interest. The ocular structures of retina have to be optically transparent for image formation. Thus, with suitable methods, the retina is visible from the outside, making the retinal tissue, and thereby the tissue of brain, accessible for imaging non invasively. Research works show that microvasculature of retina and brain is closely linked in terms of anatomy and physiology [2].

Cardiovascular disease manifests itself in the retina different ways. Hypertension and atherosclerosis cause changes in the ratio between the diameter of retinal arteries and veins, Thinning of the arteries and widening of the veins is associated with an increased risk of stroke. Retinal arterioles share similar anatomical, physiological and embryological characteristics with cerebral arterioles. Researchers have suggested that microaneurysms or arteriolar narrowing seen in the retinal circulation are risk factors for cerebrovascular disease such as stroke.[2]Hypertension can also cause direct retinal ischemia, which causes retinal infarcts visible as cotton wool spots and choroidal infarcts visible as deep retinal white spots. Also, systemic vascular disease can cause arterial and venous occlusions, known as central and branch arterial occlusions and central and branch venous occlusions .Morphological changes in blood vessel shape, branching pattern, width, tortuosity ,appearance of retinal lesions, branching angle, branching coefficient and fractal dimension are some of the abnormalities in vascular pattern of retina associated with cardiovascular diseases like stroke.

2 Literature survey

The idea of Retinex was conceived by Edwin Land [3] as a model of lightness and color perception of the human vision. Edwin Land coined word for his model of human color vision, combining the retina of the eye and the cerebral cortex of the brain. The Retinex is a human-perception based image processing algorithm which provides color constancy and dynamic range compression.

Daniel J. Jobson et al. has proposed multiscale retinex [4], which fills the gap between color images and the human observation of scenes. The enhanced image has good dynamic range compression and color constancy but this technique fails to give good color rendition.

Youhei Terai et al. [5] proposed a retinex model for color image contrast enhancement.The luminance signal is processed to reduce the computation time without changing color components. The algorithm performs better for gray images rather than color images.A color image enhancement algorithm based on human visual system based on adaptive filter is proposed by Xinghao Ding et al. [8]. The algorithm utilizes color space conversion to obtain a much better visibility. The algorithm has better effectiveness in reducing halo and color distortion.

Yali Feng et al [9] introduced the fast Fourier algorithm into the original algorithm to make the speed faster than that of the conventional method. The method is good for color images but not for gray images.

HT Nguyenl et al. [11], proposed a multilayer feed forward network for the classification of Diabetic Retinopathy. María García et al. [12] used a multilayer perceptron (MLP) classifier to obtain a final segmentation of HEs in the image. In [13] Alireza Osareh et al. classified the segmented regions into two classes, exudates and non-exudates by comparing the performance of various classifiers. Jian Wu et.al [14] proposed a cerebral aneurysm recognition method using Bayesian classification.

In [15], Yosawin Kangwanariyakul et al. proposed to use Back-propagation neural network (BPNN), the Bayesian neural network (BNN), the probabilistic neural network (PNN) and the support vector machine (SVM)for developing classification models for identifying IHD patients. Lili Xu and Shuqian Luo in [16] used a support vector machine (SVM) with Gaussian radial basis function as a classifier to identify hard exudates from digital retinal images. In [17], Priya et al. used SVM for the detection of diabetic retinopathy stages using color fundus images. Another work by the same authors [20] implemented artificial neural networks for the prediction of stroke using symptoms and risk factors as the input parameters.

3 Proposed Method

The major blood vessels of the retina are radiated from the center of the optic disc. The information of blood vessels, such as length, width, tortuosity and branching pattern can provide information on pathological changes and can automatically diagnose the disease. Optic Disc is normally modeled as a circle. Its radius and center coordinates can be directly selected in the input image. Once the optic disc is located, the user can set several radii of interest centered at the optic disc, where the vessels will be analyzed. The images were cropped using a mask to cover a region of interest corresponding to a circle of 4 OD diameter centered at OD center. [19]

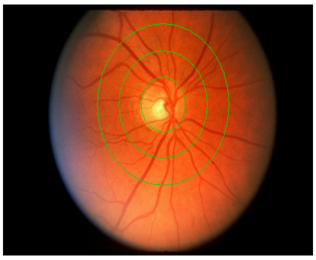


Figure. 1 Detection of Optic Disc and the Zone to be analyzed

Then preprocessing can be implemented to remove the problems of uneven illumination. Multiscale retinex has been implemented in this work for the pre processing of retinal images. Morphological operations are done for the removal of noisy background. For proper vessel segmentation, thresholding can be used to create binary images. To reduce all objects in the vascular map to lines, skeletonization is done. Branching points are detected and parameters like mean diameter, major axis length, eccentricity, fractal dimension and tortuosity are computed. These features have been calculated for healthy retinas, retinas of patients with diabetic retinopathy, hypertensive retinopathy, retinal ischemia and classification is done using Support Vector machine (SVM).

3.1 Image Acquisition

A set of 20 images of diabetic Retinopathy acquired using a Canon CR5 non-mydriatic 3CCD camera with a 45 degree field of view (FOV) is taken from DRIVE database [18]. A set of 20 Images of hypertensive retinopathy were taken from VICAVR database [24] which have been acquired with a TopCon non-mydriatic camera NW-100 model .Twenty images of Retinal ischemia has been obtained from Retina Image Bank (ASRS).15 retinal images of healthy persons have been selected both from HRF (High Resolution Fundus) database and DRIVE database.

3.2 Pre-Processing

The contrast of medical images is very low and as well as have strong speckle noise. De-noising these speckle noise has become the most important step in medical image processing. The Retinex is a type of preprocessing technique that can be applied to retinal images and is established at the scientific experiments and the scientific analysis. Retinex is a very versatile automatic method which can provide sharpening, color constancy, dynamic range compression and color rendition simultaneously.

In Single Scale Retinex (SSR) instead of applying logarithmic function on the image, the image signal is passed through the Gaussian filter called retinex filter. The output of the retinex filter is used only for scaling the original image signal such that the pixel values are scaled by different weights based on filter output. Logarithmic function is then applied on scaled image. Image filtering using retinex function may require different Gaussian shaped impulse response with different variance. So, MSR (Multiscale Retinex) approach [10] is used.

SSR is mathematically expressed as

$$Ri(x1, x2) = \log\big(Ii(x1, x2)\big) - \log\big(Ii(x1, x2) * F(x1, x2)\big) \quad (1)$$

F is a Gaussian filter defined by

$$F(x1, x2) = k \exp[-(x1^2 + x2^2)/\sigma^2] \quad (2)$$

The MSR can be written as

$$R(x, y) = \sum_{k=1}^{K} \mathrm{W_k} . \{\log[\mathrm{Ii}(x, y)] - \log[\mathrm{Ii}(x, y) * \mathrm{F_k}(x, y)]\} \quad (3)$$

Surround function is,

$$F_k(x, y) = k \exp[-\frac{x^2+y^2}{\sigma k^2}] \quad (4)$$

The MSR estimates scene reflectance from the ratios of scene intensities to their local intensity averages. The scene is decomposed into a set of images that represent the mean of the image at various spatial resolutions by applying Gaussian filters of different sizes. A set of images that measure the scene reflectance is produced by dividing the original picture point wise by the decomposed picture. A log function is applied to each of the images to reduce the image dynamic range. By adding the compressed images together, the displayed image is finally reconstructed.

Figure.2 shows the block diagram of multiscale retinex preprocessing.

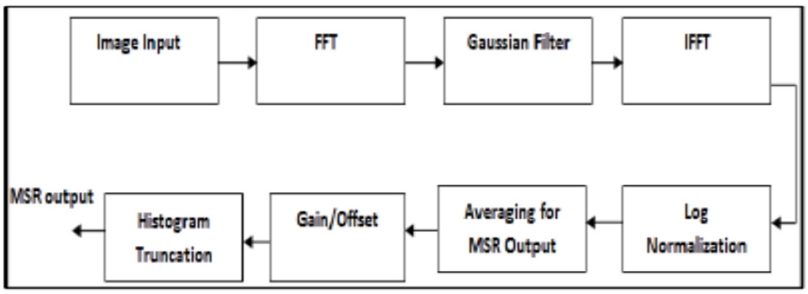


Figure. 2 Block diagram of Multiscale retinex

3.3 Morphological operations

The output image obtained after retinex preprocessing is subjected to morphological operations. MATLAB Toolbox function strel constructs structuring elements with a variety of shapes and sizes. The morphological opening function with disc shaped structuring element is applied on this binary image to remove the noisy background.[6]

3.4 Binarization

After removing the background, image is then converted to binary form by applying thresholding. A binary image B can be obtained from a gray scale or color image through an operation that selects a subset of the image pixels as foreground pixels, the pixels of importance in an image analysis task, leaving the rest as background pixels to be ignored. The selection can be as simple as thresholding operation that chooses pixels in a certain range of gray-tones or it may be a complex classification algorithm.

3.5 Skeletonization

The structural shape of a plane region can be reduced to a line graph called skeleton. The skeleton of the region can be obtained by a thinning algorithm. It is a way to reduce binary image objects to a set of thin strokes that retain important information about the shape of the original object. After obtaining skeletonized output, the branching points of skeleton are detected and the lengths of branches are calculated.

3.6 Feature Extraction

After performing the above operations, the features of the processed image need to be extracted. MATLAB function bwdistgeodesic computes the geodesic distance transform of the binary image. A set of properties for each connected component in the binary image are computed. They include parameters [7] like eccentricity, orientation and major axis length .Mean diameter, tortuosity and fractal dimension has also been evaluated. Number of branching points can also be computed from the skeletonized image.

3.6.1 Mean Diameter:

An estimate of vessel diameters is calculated using the distance transform of the inverted binary preprocessed image. This gives the Euclidean distance of every 'vessel' pixel from the closest non-vessel pixel, and therefore doubling the maximum value of the distance transform along the thinned centrelines provides an estimate of the diameter of every vessel segment at its widest point [22]. Then, the mean diameter is computed.

3.6.2 Tortuosity:

The clinical recognition of abnormal retinal tortuosity is significant in the diagnosis of several ocular and systemic diseases. Tortuosity is best described as the meanderness of the vessels, and engorgement in the diameter of the vessel. This method employs the basic idea of numerical integration [21] to determine the value of curvature for the retinal vessel curves from the detected blood vessels. The curvature value can be calculated by the ratio of the path length (L) and the shortest path (C).

3.6.3 Fractal Dimension

Fractal analysis could be applied in automated diagnosis of retinal diseases since retinal vessels are fractal. Fractal dimension [19] is a complexity indicator determined by reactive vessels obtained from vascular tracking through the box counting dimension method. After vessel tracing was ascertained, D_f is computed from the refined skeletonized vessel tracing using the Box-Counting method. The box counting equation briefly is:

$$D_f = lim_{r\to 0}\log(N[r])/\log(\frac{1}{r}) \tag{5}$$

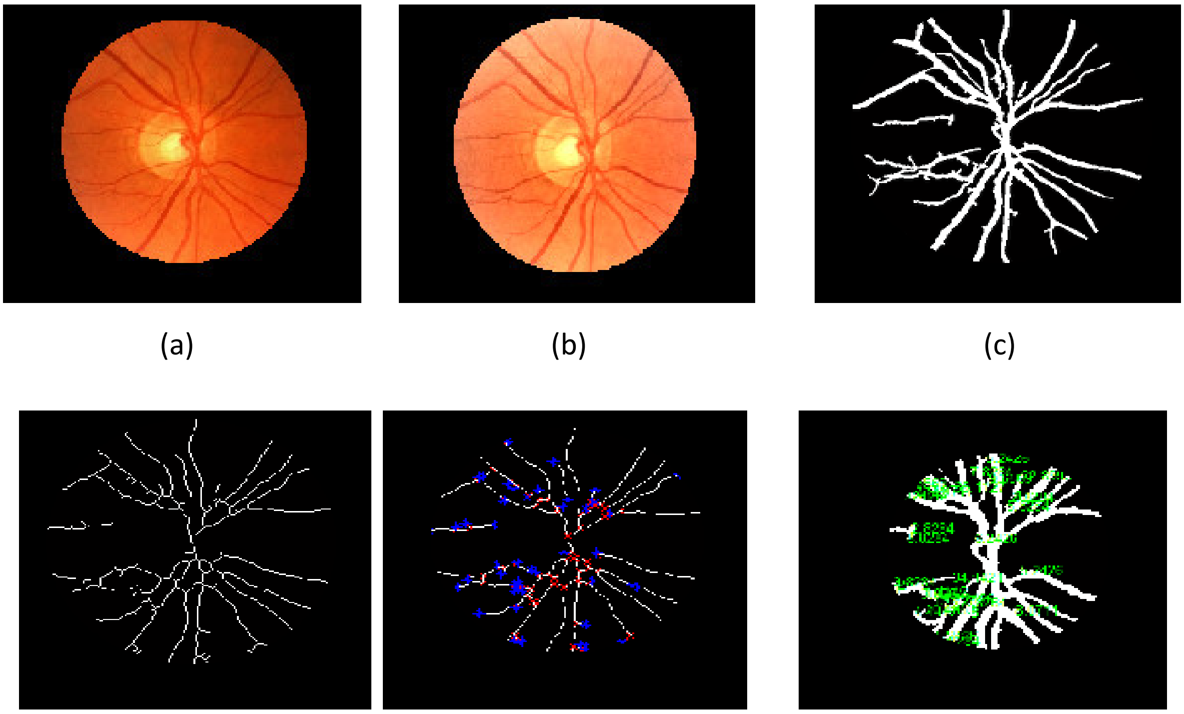
Where *N*(*r*) is the number of boxes overlying a fractal structure and *r* is the side length of each box.

3.7 Classification

This work focuses on the development of an artificial neural network model with 6 input parameters and 4 output classes for the prediction of retinal eye disease .Special importance is given to the prediction of retinal ischemia as it is an initial symptom for the occurance of stroke. The number of input nodes are determined by the finalized input data, the number of hidden nodes are determined through trial and error method and the output nodes determines the number of output classes. Here, a multilayered feed forward neural network has been designed with 6 input nodes, a hidden layer with 8 hidden nodes and 4 output nodes. Backpropogation algorithm [23] with sigmoid activation function is used to train the feed forward neural network architecture.

4 Results & discussion

The various output stages before feature extraction is shown in Fig. 3



(a) (b) (c)

(d) (e) (f)

Figure. 3 Various Output Stages of a healthy retinal fundus image

Cropped healthy retinal image (b) Retinex preprocessed image (c) Binarized image

(d) Skeletonized image (e) Detection of branch points and end points (f) Computing length of branches

The all dataset have been divided into 3 classes. Using the training dataset, the recognition accuracy is 100 % and using (i) testing dataset of 22 samples, the accuracy is 89 %

ii) testing dataset of 37 samples, the accuracy is 85 % .

Table 1 shows the recognition accuracy for various training and testing datasets.

Table 1. Accuracy for various datasets

Number of patterns in training dataset	Number of patterns in testing dataset	Recognition Accuracy
53	22	89 %
50	50 (same training set)	100 %
37	37	85 %

The performance plot of ANN with backpropogation is shown in Fig.4

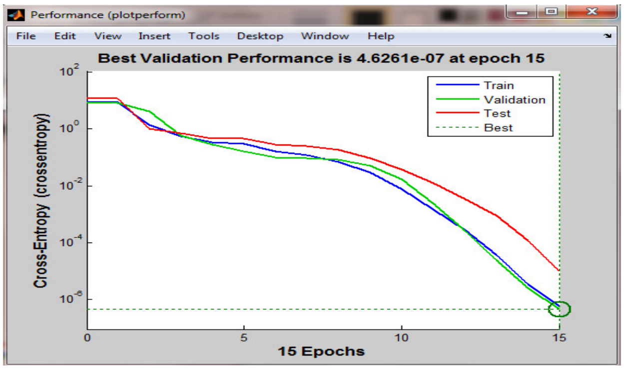


Figure . 4 Performance plot of ANN

Validation requires the calculation of statistical parameters like sensitivity, accuracy, precision and F1 score. The ability of the method to identify correct cases is given by Sensitivity. The fraction of correct classifications to the total number of classifications is given by accuracy. Precision is the likelihood that a retrieved case is relevant. F1 Score gives the harmonic mean of precision and recall (sensitivity).

Table 2 shows the statistical parameters evaluated for an ANN classifier.

Table 1. Evaluation of statistical parameters

Accuracy	Precision	Sensitivity	F1 Score
89 %	100 %	89 %	94 %

Observation shows that ANN can be used in predicting the probability of eye diseases as it was able to give an accuracy of 89 %. Retinal ischemia proves to be an important biomarker of stroke and so special significance should be given in the prediction of retinal ischemia as it can predict the possibility of occurrence of stroke.

5 Conclusion

A neural network model developed in this work for the prediction of eye diseases was able to achieve an accuracy of 89 %. Retinal imaging aids in predicting the probability of stroke based on parameters evaluated from the vascular map of retinal ischemia. Early detection of cardiovascular diseases like stroke through biomarkers derived from retinal imaging would allow patients to be treated more effectively. Performance of the system can be improved by incorporating more features like A/V ratio of the branching vessels and requires training from a much larger database. Interdisciplinary teams will be able to explore the interface at the border between ophthalmology, neurology and computing science .Since the microvasculature of brain and eye are interlinked ,it can be confirmed that *in vivo* retinal neurovascular measures are predictive of microvascular change in the brain .

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