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A Novel Approach to Diagnose Diabetic Retinopathy

Dharmanna Lamani
Department of Computer Science and Engineering, S.D.M. Institute of Technology, Ujire, 574240, India,
Email: dharmannasdmit@gmail.com

T C Manjunath
Principal, H.K.B.K.College of Engineering, Bangalore, 560045, India.
Email: tcmanjunath@gmail.com

Mahesh M
Asst. Prof., S.D.M. Institute of Technology, Ujire, 574240, India.
Email: Mahesh.m12@gmail.com

Y S Nijagunaraya
Professor, Siddaganga Institute of Technology, Tumkur, 572120, India.
Email: nijagunarya@gmail.com

Abstract—Early identification of diabetic retinopathy is highly beneficial for preventing the progression of disease. Appearance of blood vessels & retinal surface is a good ophthalmological sign of diabetic retinopathy in fundus images. In this paper, a novel method involving two approaches has been proposed for diagnosis of diabetic retinopathy. The first approach deals with estimation of fractal dimension of lesions by applying power spectral fractal dimension algorithms. For healthy retinas, fractal dimensions are found to be in the range of 2.00 to 2.069, whereas for retinas with diabetic retinopathy, fractal dimensions exceed upper limit. In the second approach, Gray Level Co-occurrence Matrix method is used to analyze the extracted regions from healthy and diabetes affected fundus retinal images. Texture features such as entropy & contrast are computed for healthy and unhealthy regions. These texture features are compared with fractal dimensions. The authors observed positive correlation between entropy and fractal dimensions, whereas negative correlation with contrast and fractal dimensions. Detailed implementations of the proposed work are presented.

Index Terms—Diabetic Retinopathy, Fractal Dimension, Entropy, Gray Level Co-occurrence Matrix.

I. Introduction

During image formation in human eye, reflected light from the object falls on retina through lens structure. The receptor and neural cells send these image signals in the form of electrical signals to brain for image perception. Such an elevated cellular activity in retinal tissue requires lot of oxygen supply. Because of this the retinal tissue is highly vascularized with many tiny blood vessels supplying nourishment. Hence, study of geometric description of vasularization of retina is of great importance to understand and treat many diseases related to eye. Diabetic retinopathy is a condition occurring in individuals associated with diabetes, which causes damage of retina progressively. The blood vessels that nourish retina is damaged due to prolonged and uncontrolled diabetes, finally leading to diabetic retinopathy. These impaired blood vessels leak blood and other fluids that cause swelling of retinal tissue and clouding of vision. Background or NonProliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR) are the two types of diabetic retinopathy. NPDR results in a variety of diseased conditions in eye which includes microaneurysms, retinal hemorrhages, hard exudates, macular edema and macular ischemia. PDR results in vitreous hemorrhage, traction retinal detachment and neovascular glaucoma. Such conditions usually affect both eyes causing blindness, if left untreated.

Microaneurysms are the small bulges in blood vessels of retina that often leak fluid. The tiny spots of blood due to leakage into the retina cause retinal haemorrhages. Also, deposition of cholesterol and other fats from blood leakage causes hard exudates. The early detection of such diseased conditions through analysis of retinal images may prevent blindness. Advancements in retinal imaging technologies have provided researchers and clinicians an upper hand in the diagnosis of retinal diseases. In the present work, fractal dimension has been employed as a useful parameter.

Fractal is an object having two properties: self-similarity and fractal dimension [14]. If the object is exactly similar to itself when scaled down or scaled up, then such a property of the object is called self-similarity. On the other hand fractal dimension is nothing but

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self-similar dimension, D, and is given by the expression

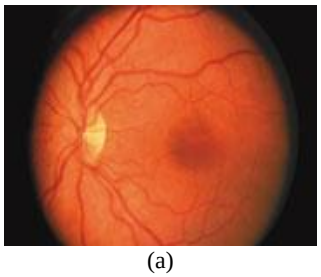
$$D = \log(N_r)/\log(1/r)$$

where *Nr* is the number of self-similar objects when the object is scaled down by ratio *r*.

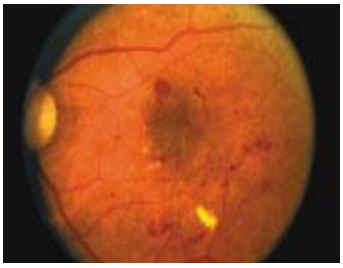
Fractal dimension (FD) has its significance in various applications including image processing. It is an ideal tool to measure the roughness/ texture of a digital image [17].

A. Literature review

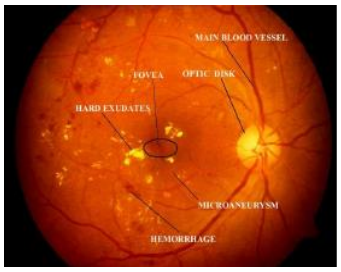
To characterise the irregular patterns of blood vessels in diabetic affected retina, Box Counting method was used to estimate the fractal dimension [19]. It was concluded by Nazneen Akhter et.al, that, as the complexity of structure of a diabetic retina increases, fractal dimension also increases. But, a baseline or a threshold value of the fractal dimension was not declared so that a retina could be classified as diabetic or not. This lacuna was taken into account for the present research work. Higuchi's Fractal Dimension was measured in circumferential direction (FDC) with respect to Optic Disk (OD), in three concentric regions between OD boundary and 1.5 OD diameters from its margin.This estimation was used as a stroke prediction marker [7]. Other method used to estimate fractal dimension include sandbox method which shows its inefficiency in case of inhomogeneity retinal structure [20].The geometric parameters of diabetic retina like central retinal arteriolar and venular equivalents (CRAE, CRVE), fractal dimension, length-diameter ratio, branching angle and curvature tortuosity were assessed by Myra Poon et.al [5]. These parameters were compared with healthy retinal images without vitamin D deficiency. The authors concluded that diabetic retinopathy is associated with high central retinal venular equivalents in diabetic persons.



(a)



(b)



(c)

Fig.1. (a) Healthy retina, (b) retina showing signs of diabetic retinopathy, and (c) Retina with component labeling

The colfilt filter was used by Chandrashekar M patil [8] to extract features from retinal images like blood vessels, exudates and microaneurysms. Then area of each feature was determined to classify the severity of disease. Geometric features and correlations were used to detect and distinguish among various features of retinal fundus images by Ravishankar et.al [10]. The success rate for optic disc localisation was 97.1%. To detect exudates, a sensitivity of 95.7% and specificity of 94.2% was achieved by the authors. Manoj Kumar et.al [12] modified Clarke's original Triangular Prism Surface Area Method to estimate fractal dimensions of gray scale images. The effects of noise on the values of fractal dimensions of digital images were discussed by T. Pant [13]. Gaussian noise, salt and pepper noise and speckle noise were applied to the digital images to generate noisy images. The fractal dimensions of these noisy images were compared with those of original images. Hard exudates in retinal image were detected using K-means clustering method and probabilistic neural network was used to train data for feature extraction by R. Radha et.al [15]. Hence, the present work emphasizes on estimation of power spectral fractal dimension, entropy and contrast to compare Diabetic Retinopathy (DR) and healthy retina.

The present research work is organized as following sections. Section1 presents introduction to diabetic retinopathy, image features, fractal dimension and past work done by various authors. Section 2 describes the methodology of work, mathematical equations and pseudo code. Section 3 presents a detailed discussion of results and comparison with clinical methods. Finally, section 4 presents conclusion of the work.

II. METHODS

This section describes the power spectral fractal dimension, computation of H Value, Gray level scale co-matrix method, related pseudo codes etc. as follows.

A. Power spectral fractal dimension

This method is based on fractal Brownian motion. Fourier transformation is applied for each line height profile that forms the image & power spectrum is estimated. Then entire power spectrum is averaged. Finally fractal dimension is estimated using the following equation.

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$$D_F = \frac{3D_T + 2 - \beta}{2}$$

where D_F is power spectral fractal dimension, D_T is the topological dimension (in this case D_T=2) and β is the spectral parameter which is defined by the following equation.

$$\beta = 2H + D_T$$

where H is the Hurst index or exponent. The estimation of Hurst index is explained below.

B. Estimation of Hurst exponent

The fractal dimension provides information of the irregularity of surface. According to equation of D_F, the fractal dimension is directly related to Hurst index for a self similar data set. A lower Hurst index value has a higher FD & more irregular or rougher surface. On the other hand, a larger Hurst index has a lower FD & a smoother or more regular surface. This is shown in Fig.2. The figure 2 also describes generates one dimensional fractional Brownian motion 'W' on t in [0, 1] using 'n' grid points. Where n denotes number of grid points and t denotes the time.

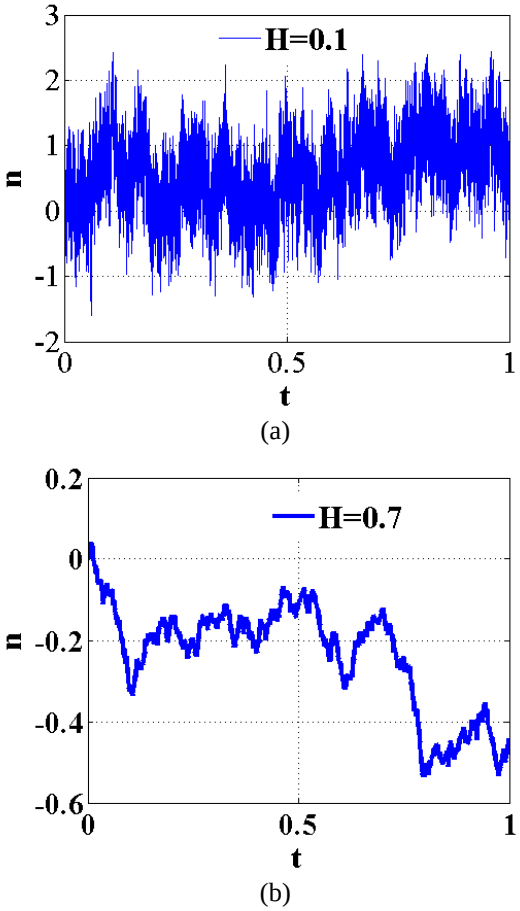

Fig.2. Fractional Brownian motion for different values of the Hurst parameter H. (a) H= 0.1 & (b) H= 0.7

Estimation of Hurst index through rescaled range method is explained in the following section.

C. Computation of rescaled range algorithm

Estimation of H index using rescaled range algorithm has been defined by many authors [18]. The equation is given below.

$$E[\frac{R(n)}{S(n)}] = Cn^H$$

As shown in fig.3, the rescaled range was estimated for the whole data set (in step1 $RS_{mean0} = RS_0$). In next step, rescaled range was computed for two halves of the data set, which is RS_0 & RS_1.Then average of these two values is determined (i.e.RS_{mean1}). Similar process continues by subdividing each of the last section in half & computing the rescaled range for each of next section. In every section rescaled range values are averaged. In the present work the algorithm stops at four data points for further subdivisions.

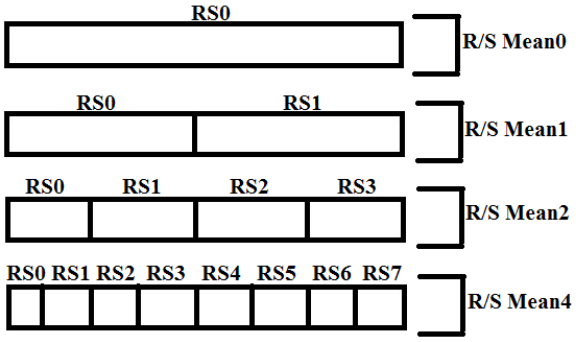

Fig.3. Description of rescaled Range algorithm

Hurst exponent estimation using the rescaled range method vector was generated, where $x_i = \log_2(n)$ is the region size of each section used to calculate R. and y_i is the $\log_2$(RS mean of i^{th} section) as shown in Table 1.

Table1. Example of computing H values

SL. No	Region Size	RSmean	$X_i=\log_2(n)$	$Y_i=\log_2$(RSmean)
1	1024	110	10	6.7814
2	512	60	9	5.9069
3	256	35	8	5.1293
4	128	23	7	4.5236
5	64	15	6	3.9069
6	32	7	5	2.8074
7	16	5	4	2.3219
8	8	4	3	2.00
9	4	2	2	1.00

The H value is calculated by linear regression line (LRL) using above points. A line has the form y=mx+b, where m is the slope of line & b is the y intercept. LRL was estimated using Table 1 data points. The value of b is -0.40& slope m is 0.70 in LRL equation as shown in Fig.4. Thus a slope of m is the computation of Hurst index. Hence Hurst index is equal to slope of the line.

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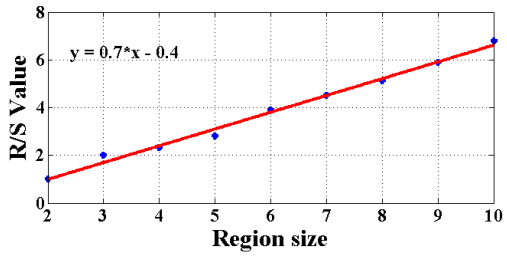

Fig.4. Generalized graph of Hurst estimation using rescaled range method

D. Pseudo code

Calculate H- value using rescale range algorithm from discrete time sequence X_i of length N.

Set k=2, m=0:

Loop m+k-1 ≤ N

$$\text{Ave} = \frac{1}{N}\sum_{i=0}^{n} X_i \quad \forall \quad i = 1, 2.... N$$

Generate average – adjusted series

$$Y_t = X_t - \text{Ave} \text{ for all } t = 1, 2, 3.....$$

Generate the cumulative deviate series Z

$$Z_t = \sum_{i}^{t} Y_t \text{ For all } t = 1, 2, 3.....$$

Find minimum and maximum values

$$Z\min = \min(Z_1, Z_2, ...Z_n)$$
$$Z\max = \max(Z_1, Z_2, ...Z_n)$$

Determine the range R

$$R(m) = Z\max - Z\min$$

Add starting one to starting index m = m+1 Generate the SD

$$S(m) = \sqrt{\frac{1}{N}\sum_{i}^{n}(X_i - \text{Ave})^2}$$

End loop

Plot algorithm graph for log R(n) versus log S(m)

For all m = 1, 2, 3.....m

Compute the slope of line and Report slope as H value

E. GLCM Method

Gray level co-occurrence matrix method is a popular second order statistical method of obtaining texture features from retinal images. Haralick defined fourteen texture features with respect to GLCM method. In this paper two features such as entropy and contrast are selected for analysis of ROI of diabetic retinopathy and healthy retina.

F. Entropy

Entropy is used to estimate the loss of information in images. It is also used to measure the randomness of pixel intensities in the image. Entropy is defined by the following equation.

$$\text{Entropy} = \sum\sum -P(x,y)\log P(x,y)$$

G. Contrast

Contrast is used to distinguish between the darkest and brightest regions of the image. The contrast is defined by the following equation.

$$\text{Contrast} = \sum\sum (x-y)^2 p(x,y)$$

H. Pseudo code of GLCM method

Step 1: Im1 ← imread('retinal-image.jpg');
Step 2: Im2 ← rgb2gray(im1)
Step 3: Im3 ← Im2(:, :, 2)
Step 4: Im4 ← imcrop(Im3)
Step 5: Im5 ← imresize(Im4,[64 64])
Step 6: Im6 ← imcomatrix(Im5)
Step 7: Glcmprops ← graycoprops(Im6)
Step 8: Write (Glcmprops)
Step 9: Record entropy and contrast and continue from step1

III. Result and Discussion

The retinal images of individuals associated with diabetes are analyzed to determine the amount of complexity associated with retinal components such as macula, optic nerve head (ONH), RNFL layer and blood vessels. Images of diabetic retinopathy and healthy retina (each 50 subject) are considered in order to evaluate the texture & fractal dimension features. The distribution of ONH, blood vessels and macula form a highly complex retinal pattern which differs among individuals. Hence it is a tedious task to examine such a complex structure with any standard (reference) retina in the diagnosis of diabetic retinopathy. Fractal theory is well-suited to quantify such a rough surface.

The retinal images were color fundus images of resolution 720x576 collected from SDM hospital Dharawad, Karnataka.In order to diagnose the disease from the images of retina, high resolution images (720x576) were employed for both healthy & diabetic retinopathy retina. Fractal dimension was estimated & utilized to quantify the patterns in terms of complexity of structure. The FD was computed using power spectral fractal dimension method which is best suited for such applications. Also texture feature of healthy & affected (diabetic retinopathy) regions were analyzed and compared with fractal dimension. In our present research

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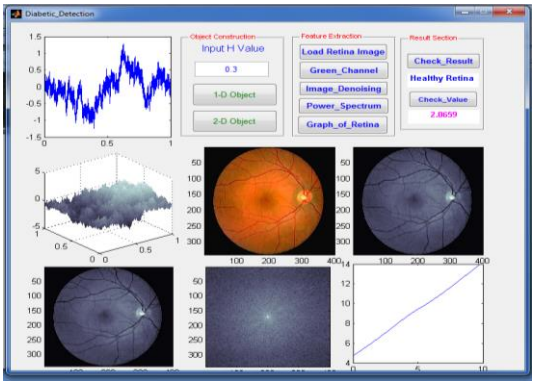
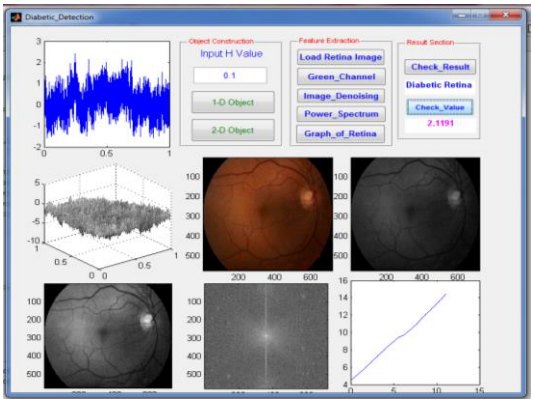
work we have designed a graphical user interface (GUI) in MATLAB 7.10.0.499 (R2010a) version. The simulation results of healthy and diabetic retinopathy are shown in Fig 5.

The Figs. 5 (a) & (b) describe the step by step process to estimate the fractal dimension of healthy & diabetic retinopathy respectively. First two steps in Fig. 5(a) & (b) show the construction of 1-D & 2-D objects based on Hurst exponent. We can observe in first two steps that objects are more rough/irregular for lower Hurst values.

In step 3, the retinal images (healthy & unhealthy) were loaded for further processing. Then Retinal images were enhanced by applying two filters. Using first filter, green channel was obtained from the color fundus images, since green channel component gives high intensity as compared to other two channels (red &blue channels) as shown in step 4. In second filter, green channel image is normalized for further enhancement as shown in step 5. In next stage (step 6), power spectrum was obtained using Fast Fourier Transformation (FFT). Then 2-dimension power spectrum image is converted into 1-dimension array using reshape function. Then Hurst exponent is computed using rescale range algorithm. Finally fractal dimension was estimated using power spectrum fractal dimension method as shown in last step. For healthy retina, fractal dimension is in the range of 2.035 to 2.069 where as for diabetic retinopathy, it exceeds the upper limit. Fig.6 (a) describes the comparison result of clinical method & proposed method. We observe in Fig 6 (a) that blue dots represent healthy retinal values, pink dots represent medium or mild diabetic retinopathy values and red dots represent the severe diabetic retinopathy values. Fig. 6(b) shows linear result between proposed method & clinical method with equation FD=0.033*x+2. Fig. 7 shows the comparison results of healthy retina & diabetic retinopathy power spectral fractal dimension values. Table 2 shows the first order statistical value of proposed method for healthy retina, diabetic retinopathy and severe diabetic retinopathy.



(a)

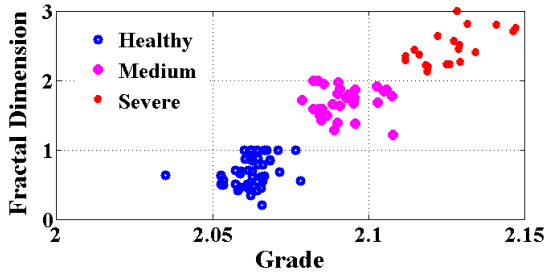


(b)

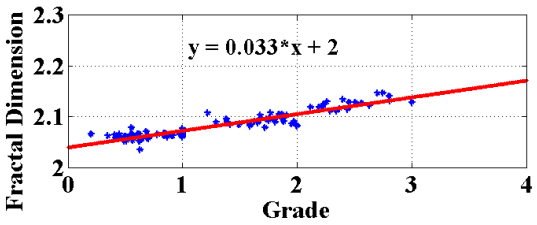
Fig.5. (a) simulation result of healthy retina and (b) Diabetic retinopathy

Table2. Statistical values of healthy retina, medium loss retinopathy, and severe loss retinopathy

	features	*Healthy retina FD value (Grade-1)*	*Medium Loss (Retina) FD Values (Grade-2)*	*Severe Loss (Retina) FD Values (Grade-2)*
1	*Min*	*2.035*	*2.079*	*2.112*
2	*Max*	*2.078*	*2.108*	*2.147*
3	*Average*	*2.062*	*2.092*	*2.126*
4	*Median*	*2.062*	*2.090*	*2.127*
5	*Mode*	*2.053*	*2.082*	*2.117*
6	*SD*	*0.00677*	*0.008082*	*0.0103*
7	*Range*	*0.0433*	*0.0292*	*0.0354*



(a)



(b)

Fig.6. (a) Graph plotted FD V/S Grading and (b) shows linearity between FD and clinical method

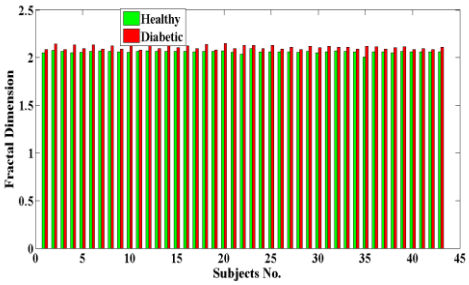


Fig.7. Fractal dimension bar chart plotted for healthy and diabetic retinopathy images

IV. Texture Feature Analysis

Texture features such as entropy & contrast are analyzed from ROIs of diabetic affected retina & healthy retina. In Table 3 first sample is of diabetic affected region of retina, where as second sample shows healthy region of retina. Generally entropy is higher for higher random region or image. Hence we can observe that first sample has higher randomness because of formation of microaneurysms, hard exudates, hemorrhages etc, whereas second sample is much smoother. Hence entropy is higher for the diabetes samples as compared to healthy retinal samples. Whereas for contrast, on other hand, we can observe that second sample is of higher contrast because of the rich presence of retinal nerve fiber layer. Hence higher contrast is achieved for healthy region. First sample has lower contrast because of retinal nerve fiber layer loss and formation of microaneurysms.

Table3. Region of interest analyzed for analyzed for healthy and diabetic retinopathy

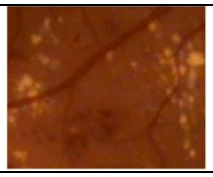
Samples		
Entropy	**0.6253**	**0.3373**
Contrast	**0.0684**	**0.1488**

Fig. 8 shows a graph plotted for contrast v/s entropy for healthy & unhealthy samples. Entropy for healthy ROI is 0.3373, whereas for unhealthy it exceeds 0.3373. Contrast for healthy ROI is in the range of 0.0104 to 0.1634 and for unhealthy samples it is in the range 0.0106 to 0.3671. Fig. 9 (a) shows a graph plotted for entropy versus fractal dimension. The blue color dots denote the result of healthy samples and red color dots denote the result of diabetic retinopathy samples. Fig. 9 (b) shows linearity between entropy and fractal dimension for non diabetic & diabetic retinopathy samples. Fig. 10 (a) shows a graph plotted for contrast versus fractal dimension. All red values denote diabetic retinopathy where as blue values denote healthy retinas. Fig. 10 (b) shows inverse relation between FD and contrast. Table 4 & 5 shows the statistical data such as min, max, mean, median, mode, SD, and range of contrast, entropy and fractal dimension values for diabetic retinopathy and non diabetic retinopathy.

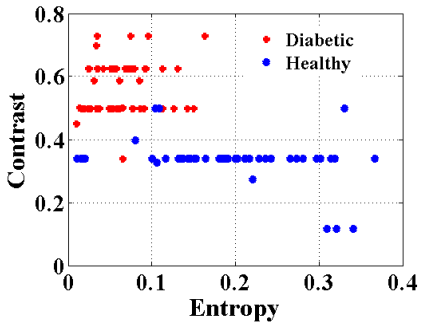
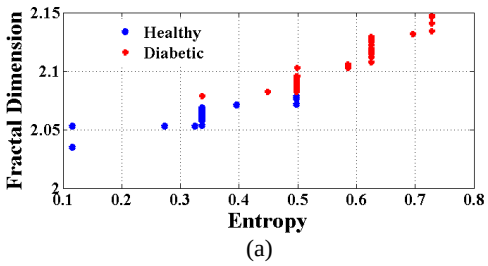
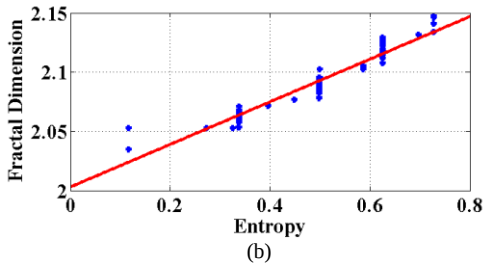


Fig.8. Graph plotted Entropy versus Contrast

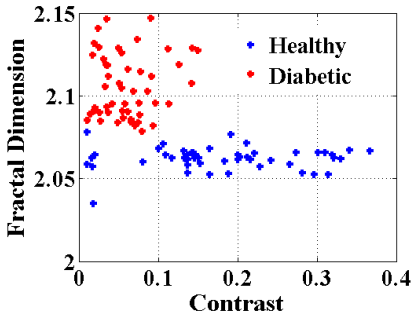


(a)

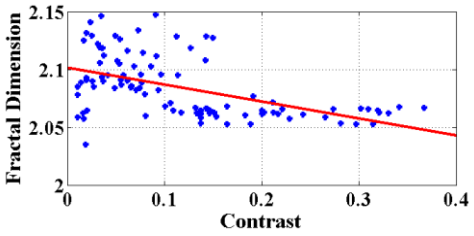


(b)

Fig.9. Graphs plotted (a) Entropy v/s FD and (b) graph shows linearity between entropy and F



(a)



(b)

Fig.10. Graphs plotted (a) Contrast v/s FD and (b) graph shows linearity between entropy and FD

Table 4. Statistical result for healthy retina

SL.No	Attributes	Healthy Retina		
		Contrast	Entropy	FD
1	Min	0.0104	0.3373	2.035
2	Max	0.1634	0.7281	2.078
3	Mean	0.06369	0.5622	2.062
4	Median	0.0569	0.4989	2.062
5	Mode	0.0104	0.498	2.053
6	SD	0.03757	0.08311	0.00677
7	Range	0.153	0.3908	0.0433

Table 5. Statistical result for diabetic retinopathy

SL.No	Attributes	Diabetes Retinopathy		
		Contrast	Entropy	FD
1	Min	0.0106	0.1161	2.079
2	Max	0.3671	0.498	2.147
3	Mean	0.1791	0.3337	2.106
4	Median	0.1726	0.3373	2.103
5	Mode	0.1374	0.3373	2.082
6	SD	0.09038	0.06485	0.01919
7	Range	0.3565	0.3819	0.0686

V. Conclusion

The diabetic disease causes gradual loss in human eye retina leading to severe deformation in veins & arteries. These characteristics are analyzed for classification of degree of complexity connected with distribution of blood veins in retina. In this article two approaches were proposed for detection of diabetic retinopathy. In first approach, each of fifty DR & healthy subjects are analyzed for classification. In second approach, texture features such as entropy and contrast are evaluated for ROI of DR and NDR subjects. Finally texture feature values are compared with fractal dimension as was shown in Fig. 9 and Fig.10. The fractal dimension, entropy and contrast can be used as diagnostic parameters to identity diabetic retinopathy from healthy retina. The present method is very attractive for ophthalmologist during the diagnosis of retinal fundus images since information obtained from proposed method can be used as additional information to increase the accuracy for detection of diabetic retinopathy.

Reference

[1] A.C.B. Kunicki, A.J. Oliveira, M.B.M. Mendonça,C.T.F. Barbosa and R.A. Nogueira, "Can the fractal dimension be applied for the early diagnosis of non-proliferative diabetic retinopathy?", Brazilian Journal of Medical and Biological Research (2009) 42: 930-934.

[2] Shueh wen lim, ning cheung, jie j. Wang, kim c. Donaghue, gerald liew, f.m. amirul islam, alicia j. Jenkins, tien y. Wong, "Retinal Vascular Fractal Dimension and Risk of Early Diabetic Retinopathy", Diabetes Care, Volume 32, Number 11, November 2009.

[3] Nazneen Akhter, Yogesh Rajput, Sumegh Tharewal, K. V. Kale, Ramesh Manza, "Fractals For Complexity Analysis Of Diabetic Retinopathy In Retinal Vasculature Images", International Journal of Research in Engineering and Technology Volume: 03 Issue: 03 | Mar-2014.

[4] Dharmanna Lamani, Dr. T. C. Manjunath, Dr. U P Kulkarni, "Automated Detection of Neovascular Glaucoma through Fractal Dimension Method", International Journal of Computer Science and Information Technologies, Vol. 5 (4), 2014.

[5] Myra Poon, Maria E. Craig, Harleen Kaur, Janine Cusumano, Muhammad Bayu Sasongko, Tien YinWong and Kim C. Donaghue, "Vitamin D Deficiency Is Not Associated with Changes in Retinal Geometric Parameters in Young People with Type 1 Diabetes", Hindawi Publishing Corporation Journal of Diabetes Research Volume 2013, Article ID 280691.

[6] Gerald Liew, Jie Jin Wang, Paul Mitchell, Tien Y. Wong, "Retinal Vascular Imaging: A New Tool in Microvascular Disease Research", Circ Cardiovasc Imaging September 2008.

[7] Behzad Aliahmad, Dinesh Kant Kumar, Hao Hao, Premith Unnikrishnan, Mohd Zulfaezal Che Azemin, Ryo Kawasaki, PaulMitchell, "Zone Specific Fractal Dimension of Retinal Images as Predictor of Stroke Incidence", Hindawi Publishing Corporation, The Scientific World Journal, Volume 2014, Article ID 467462.

[8] Dr.Chandrashekar. M. Patil, "An Approach for the Detection of Vascular Abnormalities in Diabetic Retinopathy", International Journal of Data Mining Techniques and Applications Vol: 02, December 2013, Pages: 246-250.

[9] Albert Daxer, "Characterisation of Neovascularisation process in diabetic retinopathy by means of fractal geometry: diagnostic implications", Graefe's Archieve for Clinical and Experimental Opthomology, Springer-Verlag, 1993.

[10] Ravishankar S, Jain A, Mittal A, "Automated feature extraction for early detection of diabetic retinopathy in fundus images", IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2009.

[11] Gábor Márk Somfai, Erika Tárai, Lenke Laurik, Boglárka E Varga, Vera Ölvedy, William E Smiddy, Robert Tchitnga, Anikó Somogyi and Delia Cabrera DeBuc, "BMC Bioinformatics 2014, 15:295",

[12] Manoj Kumar Rathore, Mayank Kumar, Surendra yadav, Awanish Mishra, "Estimation of Fractal Dimension of Digital Images", International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, Volume-2, Issue-9, September 2014.

[13] T. Pant, "Effect of Noise in Estimation of Fractal Dimension of Digital Images", International Journal of Signal Processing, Image Processing and Pattern Recognition Vol.6, No.5 (2013), pp.101-116.

[14] P. Pentland, "Fractal-based description of natural scenes", IEEE Trans. Pattern Anal. Mach. Intell., PAMI-6, (1984), pp. 661-674.

[15] R.Radha and Bijee Lakshman, "Retinal Image Analysis Using Morphological Process and Clustering Technique", Signal & Image Processing: An International Journal (SIPIJ) Vol.4, No.6, December 2013.

[16] Selvathi D, N.B.Prakash, Neethi Balagopal, "Automated Detection of Diabetic Retinopathy for Early Diagnosis using Feature Extraction and Support Vector Machine ", International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 2, Issue 11, November 2012.

[17] P. Shanmugavadivu, V. Sivakumar, "Fractal Dimension based Textural Analysis Digital Images", Procedia Engineering 38 (2012) 2981 – 2986.

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[18] Malhar Kale, Ferry Butar Butar, "Fractal Analysisof Time Series and Distribution Properties of Hurst Exponet", Journal of Mathematical Science and Mathematics Education, Vol. 5, Issue 1, PP. 9-19.
[19] Misson G P, Landini G, Murray P I, Fractals and Ophthalmology, Lancet 339:872.

Authors' Profiles

Dharmanna Lamani, did M.Tech (VLSI Design and Embedded system) from VTU, Belagavi, is currently pursuing his doctoral programme in Computer Science & Engineering. His research interest includes Medical Image Processing, Embedded System design, VLSI Design, Pattern Recognition and Computer Networking. He has published around 10 papers in reputed Journals and Conferences.

Dr. T.C.Manjunath, was born in Bangalore, Karnataka, India on Feb. 6, 1966 & received the B.E. Degree (Bachelor of Engg.) from R.V. College of Engg. (Bangalore Univ., B'lore) in the year 1989, M.E. degree in Automation, Control & Robotics from the Govt.'s LD College of Engg., (Gujarat Univ., Ahmadabad) in the year 1992 and Ph.D. in Systems & Control Engg. from the prestigious IIT Bombay in the year 2007 respectively. I have got a teaching & administrative experience of nearly 25 long years in various engineering colleges all over the country and is currently working as Principal, i.e., as Head of the Institution in HKBK College of Engg., Bangalore, Karnataka, India. I have published more than 500+ papers in the various National, International journals and Conferences in India & abroad and published more than a dozen textbooks. I have also published a research monograph in the International level from the Springer-Verlag publishers based on my Ph.D. thesis topic. I am Fellow of IETE, IE & Sr. member of IEEE, along with life member of ISSS, ISOI, SSI, CSI, ISTE, IETE, IE. I was awarded with the "Best research scholar award in engineering discipline" for the academic year 2006-07 from the Research Scholars Forum from IIT Bombay.

Mahesh M was born in Bangalore, India on 12th june 1977. He was graduated from University B.D.T. College of Engineering, Davangere, India, in 2004. He received his Masters degree in VLSI Design & Embedded Systems from Visvesvaraya Technological University (VTU), Belgaum, India, in 2006. Currently, he is pursuing his Ph.D. in the field of medical image processing at VTU, Belgaum, India. He is working as an Assistant professor at SDM Institute of Technology, Ujire, India, in the department of Electronics & Communication Engineering. His areas of interest includes analog design, image and video processing

Y. S. Nijagunarya was born in Mysore, India on 26th September 1960. He was graduated from Bangalore University, India. He received his Masters in Industrial Electronics from Mysore University, India. He was awarded with a Ph.D. degree from Mysore University. Currently, he is working as a Professor at Siddaganga Institute of Technology, Tumkur, India. He has a vast teaching experience of 29 years. His area of research is soft computing techniques.

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