Fractal Dimension as Diagnostic Parameter to Detect Glaucoma

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Abstract - The present paper explores a state of art for earlier diagnosis using image analysis. Authors attempted to show that fractal dimension (FD) of image feature could be adopted as alternative diagnostic parameter to detect glaucoma using state of art. At presents conventional approach to detect glaucoma ophthalmologist are using clinical parameter cup to disk ratio (CDR) which involves with lot human involvement to take decision. Authors extracted FD feature from eyes images using two algorithms Semi-variance and Box counting for a set of 80 images including male, female patients with age variations of 30 -70 years. The strong findings of the paper are: (1) Authors found that CDR linearly increasing with age of patient with FD also linearly increasing with age of patient (2) Obtained FD values are consistency with scalability of images. (3)Semi-variance algorithm merits the Box counting. (4)FD can be used as diagnostic parameters instead of CDR. Authors positively conclude that in future; FD would be very well used as diagnostic parameter for earlier detection of glaucoma.

Keywords: Glaucoma, Cup-to-Disc Ratio (CDR), Fractal Dimension (FD)

I. INTRODUCTION

Glaucoma is the second biggest age related disease that damages the optic nerve causing the loss of vision and permanent blindness [11]. Approximately 50% of the cases are undetected because of rarely symptoms in early stage [4]. At present in order to detect presence of glaucoma ophthalmologists measures the cup to disc ratio (CDR).Cup to disk ratio can range from 0.1 to 1.0 in the healthy condition to unhealthy condition. A cup to disc ratio greater than 0.5 is generally considered to be suspicious for glaucoma [8].The cup to disc ratio is a measurement used in ophthalmology and optometry to assess the progression of glaucoma. The vertical cup to disk ratio is positively associated with optic disk size in normal and glaucomatous eyes. But glaucoma, which is due to an increase in intra-ocular pressure, produces additional pathological cupping of the optic disc. Through periodic photographs of the optic nerve, the ratio of the cup to the disc can be monitored. The manual examination of optic disk (OD) is a standard procedure used for detecting glaucoma. To determine accurate cup to disc ratio is very difficult. In proposed scenario automatic retinal image analysis is an emerging method for early detection of eye disease glaucoma by measuring CDR. Fractal dimension allows us to measure the complexity of an object, that too preferably self similarity such as eye, brain, tree, mountain and so on so forth. Recently Hsiao-Wen Chung et al presented fractal analysis approach for Nuclear medicine images for the diagnosis of Pulmonary Emphysema and concluded that FD seems to be an over simplified parameter unrelated to spatial heterogeneity of images [6].Fractal analysis is potentially suitable for an objective quantification of spatial heterogeneity because it is believed to be effective in helping to characterize complex system that are hard to describe using conventional Euclidean geometry. Fractal dimension is parameter that can be determined solely by the image intensity. Hence preserving image intensity play an important role. Otherwise it is always better to adopt any suitable image enhancement techniques. The detail of the present paper is organized as follows: Section 1 presents introduction of cup to disk ratio and Fractal theory. Section 2 discuses the basic mathematical formulation to estimate CDR and FD through image Analysis. Section 3 deals with main objective and methodology associated with an algorithms to extract FD

feature from eye images. Results and discussion of the present work has been put-up in detail highlighting major deliverable accomplishment. Section 5 presents concrete strong conclusions followed by references.

II. MATHEMATICAL FRAME WORK

The basic and simple mathematical relations to be used in the present work are developed using Euclidian geometry for CDR and Fractal geometry for FD in the following sections. However the basic relation of FD is suitably customized to the algorithm used in the image analysis.

2.1 Cup-to-Disc Ratio.

The cup to disc ratio is a measurement used in ophthalmology and optometry to assess the progression of glaucoma. The optic disc is the anatomical location of the eye's blind spot", the area where the optic nerve and blood vessels enter the retina. The optic disc can be at or can have a certain amount of normal cupping. But

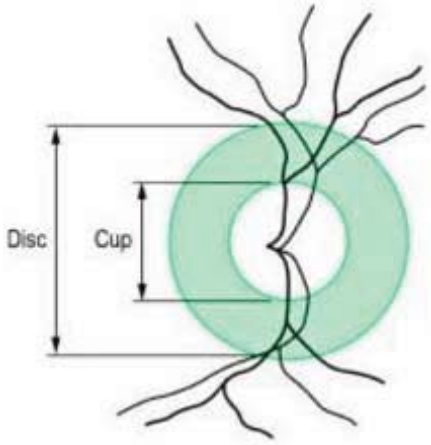


Figure.1.CDR Definition

glaucoma, which is due to an increase in intra-ocular pressure, produces additional pathological cupping of the optic disc. As glaucoma advances, the cup enlarges until it occupies most of the disc area as shown in Figure.1.The cup to disc ratio compares the diameter of the "cup" portion of the optic disc with the total diameter of the optic disc. A large cup to disc ratio may imply glaucoma. However, cupping by itself is not indicative of glaucoma. Rather, it is an increase in cupping as the patient ages which are an indicator for glaucoma. There is already well established algorithms to estimate CDR through digital image analysis elsewhere as detailed in papers [1 2 3 4].But exhaustive literature review high lights that CDR exhibits the increasing pattern as the age increases and progress of glaucoma increases and taking in to consideration that CDR=0.5 as the demarcation to identify 2.2 Fractal Dimension Everyone knows the dimension of a line, a square, and a cube. They are one, two, and three respectively. We can measure the distance, area, and volume of those objects geometry using Euclidean theory. However, what is the dimension of the inside of a eye or the brain, and how do we measure their surface area? How about a piece of broccoli or cauliower? This is where fractal dimension can help us out which is based on Fractal geometry rather than Euclidean geometry. Fractal dimension allows us to measure the complexity of an object that too preferably natural object which are self similarity such as tree, sea, brain& so on so forth? Glaucomatous and non-glaucoma eyes also natural objects.

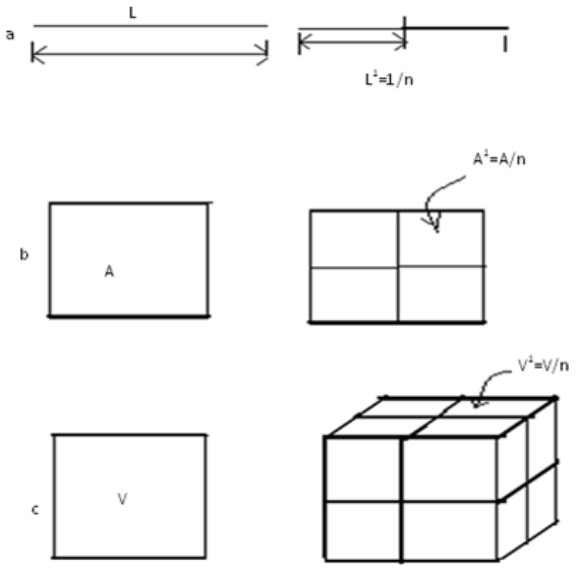


Fig 2. Fractal Dimension

2.2 Fractal Dimension

The mathematical relation of fractal dimension (D) is developed through induction Principle as explained in the following figure.2 [12]. Consider objects of straight line, Fig.2 (a), Area, Fig.2 (b) and Volume of unit quantity Fig.2(c). The fractal dimension (D) is always interrelated with scaling factor(S) and number of subdivisions (n) to which the object is subjected to subdivisions at any instant of time, which could be understood by the following induction analogy with

Examples.

Example 1: Consider a Unit length (1) of one dimensional object as shown in Fig.2 (a) and subdivided into two equal parts. S =1/n1 n=2

Cross multiplying we get n*s1=1

Example 2: Consider a Unit Area (A) of two dimensional objects as shown in Fig.2 (b) and subdivided into four equal. Parts.

s=1/n1/2 n=4

Cross multiplying we get n*s2=1Example 3: Consider a Unit Volume (V) of three dimensional objects as shown in Fig.2(c) and subdivided into eight equal parts. s=1/n1/3 n=8.

Cross multiplying we get n*s3=1.

Generalizing the above induction principle, the general relation for fractal dimension is written as,

$$n*sFD = 1.$$

Where

n=Number of subparts of object

S=Scaling factor for the object FD=Fractal dimension of the object. Logarithmic solution of equation (1), will give the relation for FD as follows. Taking log (natural) on both sides, we can write equation (1) as equation (2), solving for FD, we get equation (3).

$$\log(n) + FD:\log(S) = \log(1)$$

$$FD = \log(n)/\log(1/s)$$

In case of an extracting FD feature from images, equation (3) is customized to the approach and algorithms adopted in image analysis.

III. OBJECTIVE AND METHODOLOGY

The objective of this work is to quantify image feature in terms of FD using fractal theory proposed by father of Fractal geometry Benoit Mandelbrot. The basic mathematical framework to developed relation of FD explained in

the section 2.2 earlier. But to obtain CDR, we followed well established procedure in papers [1, 2, 3 and 8, 9]. The detailed description of present methodology is explained in the subsequent sections 3.1, 3.1.1, and 3.1.2 as follows.

3.1 Image Analysis to extract FD feature

The major task of present research explains the procedure to extract FD eye images. We consider total of 80 images which are in RGB format such that 50 are glaucoma affected and another 30 are free from glaucoma with deferent? Age varying from 30 to 70 years includes male and female patients. These images contain cup and disc parts of images. The color images are transformed in to gray scale images using suitable image tool routines because extraction of FD needs gray scale images or binary images only. The relations explained in section 2.2 are customized to deferent approaches to extract FD as detailed in section 3.1.2.

3.1.1 Approaches

We found deferent types of fractal dimension algorithms based on the literature survey. In this paper we adopted box counting and semi-variance method with medication in order to handle eye images containing only cup-disk part of eye image. List of deferent methods are as follows [10].

1. Box counting
2. Semi-variance method
3. Triangular prisms method
4. Covering blacket method
5. Sand box method
6. Cube counting method
7. Differential box counting
8. Isarithm method

3.1.2 Implementation

Box-Counting method: To obtain fractal dimension of eye image, authors adopted box counting technique. The database of eye image is developed collecting from local hospitals. All images are resized to 256X256 pixels so that image size would be in terms of power of 2 in order to account for scalability of images. In this method, eye image is treated as binary image of two dimensions metric and logical Box dimension is varied to cover entire image size. Simultaneously logarithm of No. of boxes (log (n)) and number binary number 1and 0s (log (1/S)) are counted in each known box size. To determine Fractal Dimension, log (n), log (1/S) parameters are drawn on logarithmic scale and slope of that straight line gives fractal dimension (FD). In the present work polynomial straight line fitting is adopted to determine the slope of the straight line which represents fractal dimension of given image. As the pre-processing, color images are converted into gray scale image, and then gray scale image converted into binary image by threshold values. A Box counting pseudo algorithms as follows [12].

(1)Convert color image into grayscale image.
(2)Set the threshold value to convert into binary image.
(3)Subdivide the image in power of 2 in quadrant method.
(4)Obtained log (N)\& log (1/S) for each sub quadrants iteratively
(5)Obtain slope of log (N)\& log (1/S) by straight line fitting.
(6)Slope of the straight line is reported as FD.

Semi-variance method: A Semi-variance pseudo algorithm is as follows.

(1)Convert color image into gray scale image.
(2)Select step size or displacement size.(1 2 3 4 5 6).
(3)Repeat for selected step size
(3a)Select row, determine square of pixels intensity
(3b)Make summation of all rows.
(3c)Draw log-log graph for step sizes and Summations.
(3d)Determine slope of straight, report as FD for Horizontal scanning (HS).
(4)Same procedure is adopted for vertical scanning (VS).

IV. RESULTS AND DISCUSSION.

This paper explores a state of art for earlier diagnosis using image analysis. Authors extracted FD feature from glaucoma affected and normal eye images using two algorithms Box counting and Semi-variance algorithms for set of 80 images including male, female patients with age variations of 30-70 years. The figure 3 and figure 4 shows the fractal dimension by box counting and semi-variance method respectively. The Figure 5 shows best curve fitting between age of patients and CDR and FD. It signifies that linear trend for both CDR and FD with respect to age of

patient immaterial of gender. The Table 1, 2 and 3 tabulate descriptive statistical parameters such as Mean, Median (MD), Standard deviation (SD) and co-variance (CV) obtained for 80 images amounting to total 480 FD features. The tabulated results signify that obtained FD values are reasonably consistency with scalability of images. The research results infer that earlier detection of glaucoma could be achieved automatically just by finding FD in order to avoid elaborative and human involved activities. The results also explores that Semi-variance algorithm merits the Box counting approach because first method accounts both vertical and horizontal scanning to determine FD for gray scale transformation only where as Box counting methods involves with two stage transformation namely color to gray and then gray scale image to binary image. Hence there is lot of possibility of not preserving original intensity of image in Box counting method.

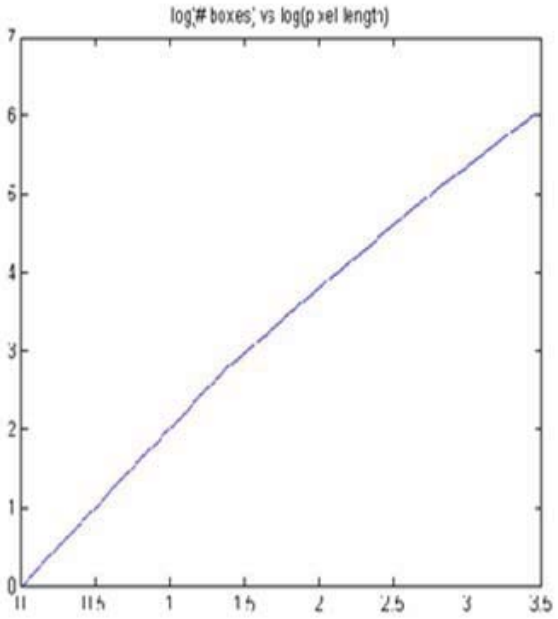


Fig 3.Fractal dimension by Box Counting

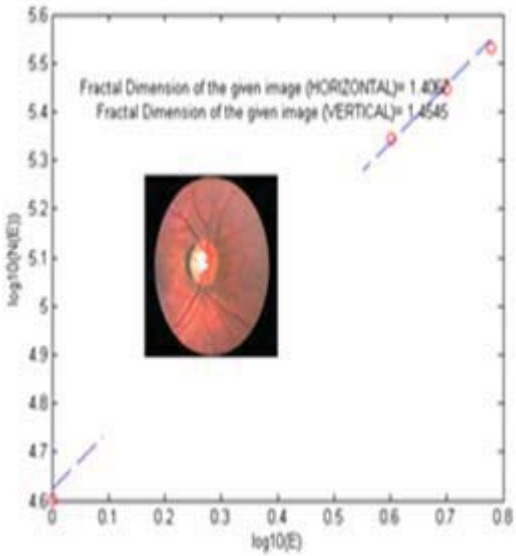


Fig 4. Fractal Dimension by semi-variance

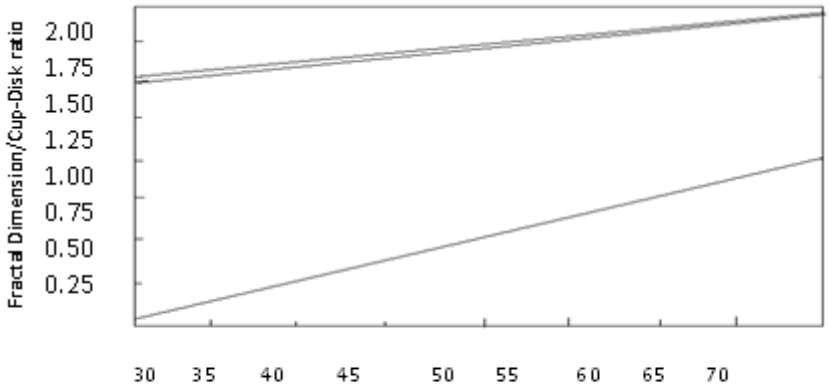


Fig5. Fractal Dimension/Cup-Disk ration Vs Age

Table1. DESCRIPTIVEST ATICTICS OF FRACTAL DIMENSION

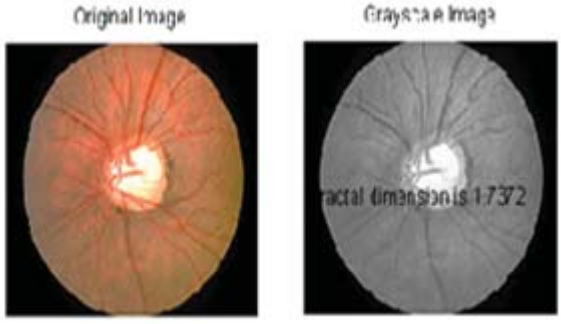
Box-counting method				
	Mean	MD	SD	CV
Men	1.88	1.88	0.06	0.03
Men	1.89	1.89	0.05	0.02
Men	1.92	1.93	0.05	0.03
Men	1.92	1.92	0.05	0.03
Women	1.92	1.92	0.04	0.02
Women	1.92	1.91	0.02	0.01
Women	1.90	1.90	0.05	0.02
Women	1.91	1.89	0.04	0.03

Table2. DESCRIPTIVE STATICTICS OF FRACTAL DIMENSION

Semi-variance method				
Mean HS	1.55	1.50	1.46	1.49
Mean VS	1.58	1.55	1.45	1.56
MD HS	1.53	1.50	1.47	1.50
MD VS	1.57	1.52	1.45	1.57
SD HS	0.05	0.01	0.03	0.02
SD VS	0.09	0.08	0.02	0.04
CV HS	0.03	0.01	0.02	0.01
CVVS	0.06	0.03	0.02	0.05

Table3. DESCRIPTIVE STATICTICS OF FRACTAL DIMENSION

Semi-variance method				
Mean HS	1.56	1.51	1.52	1.55
Mean VS	1.58	1.61	1.60	1.58
MD HS	1.56	1.51	1.52	1.47
MD VS	1.69	1.59	1.60	1.51
SD HS	0.03	0.02	0.02	0.08
SD VS	0.04	0.01	0.03	0.13
CVHS	0.02	0.01	0.01	0.05
CVVS	0.02	0.05	0.02	0.09



V. CONCLUSIONS

This paper explores the state of art for earlier diagnosis using image analysis through extraction of one single feature namely FD. Authors attempted to developed statistical relation between age of patient with CDR and FD. Authors extracted FD feature from glaucoma affected and normal images using two algorithms for the set of 80 images of male and female patients with age variation of 30-70 years. The descriptive statistical parameters as observed in the Table1, 2, and 3, signifies that FD feature values in the both methods are reasonably consistency with scalability of images. Results also signifies that Semi-variance method merits Box-counting method because of the factor that Semi-variance method accounts both horizontal and vertical scanning but not box counting method. The best curve fitting signifies that age of patient linearly correlates with CDR and FD immaterial of the gender such that CDR varies from 0.1 to 1.0 and FD varies from 1.5-2.0.Hence authors strongly conclude the following findings:

: (1) Age of patient linearly correlates with CDR and FD, immaterial of gender. (2) FD values are reasonably consistency with scalability of images. (3) Semi-variance method merits box counting method. (4) FD can be used as diagnostic parameter instead of CDR in future. Usage of FD in future for the diagnosis is also subjected to time tested procedures. Therefore, the fractal analysis when appropriately combined with conventional visual diagnosis could be of some value by providing an objective quantity to serve as an index for diagnostic reference. The rigorous statistical analysis signifies that FD feature could be very much used for the earlier detection of glaucoma disease and reinforces the task of computerized eye testing, at 95% confidence interval

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