Bidirectional Fractal Dimension through Semi Variance Applied to Glaucomatous Eye

DHARMANNA LAMANI
SDMIT
Ujire 574240

Dr. RAMEGOWDA
BCE,Shravan
Belagol

Dr. T C MANJUNATH
HKBK
Bangalore

Abstract - The present paper investigates application of bidirectional fractal dimension for earlier detection of glaucoma. Glaucoma is multi decease which causes the loss optic nerve fiber leading to permanent blindness. Ophthalmologists are attempting to diagnose the glaucoma which involve lot human interface. Hence present paper attempts to explore image analysis technique to estimate the bidirectional semivariance fractal dimension method is modified to determine to bidirectional fractal dimension. The investigation results reflect that average fractal dimension varies from for glaucoma 1.39 to 1.59 and for glaucoma ranges from 1.59 to 1.85. Hence author proclaims bidirectional fractal dimension value less than 1.59 could be used as threshold for earlier detection of glaucoma and also author found that for non glaucoma slope smooth and whereas for glaucoma very steep.

I. INTRODUCTION

An anatomy of human eye approximately a spherical organ shown in fig1(A). The protective outer layer of the eye is called the sclera. The other components of the eye are regions such as cornea, lens, iris, and retina. Retina is approximately 0.5-mm thick and covers the inner side at the back of the eye. The center of the retina is the optical disc, a circular to oval white area measuring about 3 mm2 (about 1/30 of retina area). The mean diameter of the vessels is about 250µm. The main retinal components numbered in Figure 1(B). (1)Superior temporal blood vessels, (2)Superior nasal blood vessels,(3) Fovea, (4) Optic disc, (5) Inferior temporal blood vessels and (6) Inferior nasal blood vessels

Glaucoma is deadly age related decease in the world. In glaucoma basically two types one is open glaucoma and other one is closed angle glaucoma both will leads to the permanent blindness. Glaucoma is a multiple decease which causes to loss of retinal optic fiber nerves which is shown human structured eye. The optic disk (OD) is the location where ganglion cell axons exit the eye to form the optic nerve through which visual information of the photoreceptors is transmitted to the brain. The OD can be divided into two distinct zones, namely, a central bright zone called the cup and a peripheral region called the neuroretinal rim where the nerve fibers bend into the cup region and optic disk in fig1 retinal component. The enlargement of the optic curve is signing of glaucoma it mean loss of neuroretinal rim or retinal optic nerve. Fig 1 (c) is glaucoma optic disk which can observe enlargement of cup within optic disk whereas fig 1 (d) is the non glaucoma optic disk we can observe very small cup. Diagnose glaucoma ophthalmologist an estimate vertical cup-disk diameter ratio, which should not be greater than 0.5 but in order to determine cup to disk diameter first we have to segment cup and disk which more tedious and erroneous. So, in present work we considered whole disk pixel intensity to diagnose glaucoma using fractal geometry.

Fractal geometry is developed by IBM corporation mathematician Mr. Mendole Brought it used to describe the dimension natural object such as mountain, tree, ocean waves, could and biological organs like liver, heart and eye. Whereas Euclidean geometry estimates dimension regular shape object such as line, square and cube which has dimension 1, 2 and 3 respectively but what about natural objet here comes into picture fractal geometry or fractal dimension. To estimate fractal dimension we identify the various method (1) box counting method (2) differential box counting method (3) Perimeter method (4) blacket cover method (5) power spectrum method and (6) semivariance method. In this case study we adopted semivariance method to determine the fractal dimension.

REVIEW OF PREVIOUS METHOD

The Francois Mendels et al presents [20] the changes in the shape of the optic disk and area may sign of disease process. Therefore authors identified boundary of optic disc using active counter. Optic disc is the region on the retina at which nerve axons enter and leaves the eye. However author didn’t attempted only changes in the optic cup area and optic cup boundary. The Radim Kolar and Jiri Jan describes [14] the identification of glaucoma through fractal dimension method using box counting method. Author also computed power spectrum for non glaucoma eye with retinal nerve fiber (RNF) striation in different direction. Whereas for glaucomatous eye with retinal nerve fiber loses has energies distributed more uniformly for the spectral plane. The Juan Xu et al presented [15] modified the active contour method using two techniques (1) knowledge based and smoothing updates to identify the optic disc and cup boundary. Then determining the cup-disc ratio and achieved 94% success rate compare to gradient vector flow snake (GVF) (12%) and modified ASM (82%).

The Chisako et al [21] presented automatic determination of disk which is assists to determine cup to disk ratio to diagnose the glaucoma. The author compared three method (1) Active counter methods (ACM) (2) Fuzzy c-mean (FCM) clustering
and (3) Artificial neural network (ANN) these algorithm achieved 87%, 88% and 86% respectively. However did not attempt to extract optic cup from optic disk. The author Jain Li [22] applied Differential box counting technique for texture segmentation, shape classification and graphic analysis. In this technique assign the smallest box to cover entire image surface at each selected scale as required.

The article [23] adopted semivariance method to quantify properties of texture and fabrics which is defined in terms of smooth, coarse and anisotropic. Coarse/fineness is quantified by using semivariogram ranges and rough/smoothness is quantified by using sill or optimum point. However author didn’t attempt for fractal dimension.

The author [24] Tian-yuan shis et al applied variogram method to estimate the fractal dimension of variability of sea surface. The paper [25] presents enhancement of retinal image using Gabor wavelet transfer and computed Fourier fractal dimension. The author found there was Gaussian distribution in the optic center allocation. The mean correlation coefficient was 0.93 and also found reduction is the retinal vasculation complexity with aging.

Author has organized paper as follows section (1) presents the introduction. Section (2) presents semivariance method. Section (3) describes the implantation and pseudo code. Section (4) presents results and discussion and section (5) describes the conclusion and future enhancement followed by reference.

II. SEMIVARIANCE METHOD

Consider x and x+h to be locations where a measure, Z, was taken. The locations x+h and x are separated by distance h, this indicates the distance between the samples and the relative orientation. The mean difference between all such samples as follows:

\[ m(h) = \frac{1}{n} \sum_i [Z(x) - Z(x + h)] \]

Variance according to above equation (1) is:

\[ 2V(h) = \frac{1}{n} \sum_i [Z(x) - Z(x + h)]^2 \]

In the equation (2), the term 2V(h) is called a Variogram, and the term V(h) is called a Semivariogram. The semivariogram modeling is applied for data analysis technique. The values of V(h) are plotted against the difference in distances between pairs. Inferential results are made by looking into the plotted graph.

Figure 2 shows an “general model” of one such graph with a plot showing the change in V(h) with change in the distance of separation h. The range defined as a variance gradually increases till a threshold is reached in the distance of separation. This threshold is called a range. Once the distance between two points is beyond range, the variance becomes independent of the distance and maintains a constant value. The sill is defined as maximum variance value that can be attained by the variogram is called the sill. The nugget reveals information on variability between adjacent pixels.

Semivariance defined as the mean sum of squares of all difference between pairs of values (pixels) with given distance divided by two. The standard equation for semivariance is:

\[ V(h) = \left( \frac{1}{2} N(h) \right) \sum_{i=1}^{N(h)} [Z(x_i+h) - Z(x_i)]^2 \]

Where N(h) is No. of pair of data for distance h, V(h) is the semivariance of lag distance h, x is the value (gray level intensity) of the i\textsuperscript{th} data item in a profile.

The semivariance is uni-variate estimator. This is described the relationship between the similarity and distance in the neighborhood Z(x) and Z(x+h) are two value of the variable Z located at point X and X+h.

Determine the semivariogram for each of two directions: vertical and horizontal. If we have an mxn array of pixels with gray values by X\textsubscript{i,j} (where i is the horizontal coordinates and j is vertical coordinates from top left origin) the modification of standard semivariance equation is.

(a) Horizontal direction

\[ V(h) = \left[ \frac{1}{2} M \cdot N(n) \right] \sum_{i=1}^{M} \sum_{j=1}^{N(h)} [X_{i+h,j} - X_{i,j}]^2 \]

(b) Vertical direction

\[ V(h) = \left[ \frac{1}{2} M \cdot N(n) \right] \sum_{j=1}^{N} \sum_{i=1}^{N(h)} [X_{i,j+h} - X_{i,j}]^2 \]

Where as V(h) is the semivariance, N(h) is the No. pairs and M, N are No. rows and columns ROI respectively.
Note: The x’s denote hypothetical sample variogram points computed from observed data. The smooth curve represents a theoretical variogram fitted to the sample variogram points.

III. IMPLEMENTATION

The color fundus image converted into gray level image and selected region of interest (ROI) i.e optic disk from retina image then applied semivariance algorithm. The semivariance algorithm computes fractal dimension to assess the directionality of the texture pattern in an image. Semi-variance along horizontal direction is defined as the summation over all pixels (n), of the difference in intensities $x(i,j)$ of pixels separated by the displacement ‘$h$’ in the $x$ - direction. Similarly for vertical direction, it is calculated in $y$-direction. The fractal dimensions can be calculated from the linear slope of the plots of the logarithm of semi-variance as a function of $h$. Hence fractal dimension for two directional is designated as Bi-directional fractal dimension by the present author.

PSEUDO CODE

1. Select the region of interest (i.e optic disk of retina)
2. Determine $M$ and $N$ this is total No. of row and columns of optic disk respectively
3. Set to zero for each range $h=1,2,3.....$ Sum$H$, Sum$V$, Hpair and Vpair this denotes horizontal sum, vertical sum,number of horizontal pair and number vertical pair respectively.
4. Repeat for distance $h$ from 1 to sill point
5. Repeat for rows $i=1$ to $M$
6. Repeat for columns $j=1$ to $N$
7. If column $j$ is greater than distance $h$ then
   
   $\text{SumH} = \sum_{i,j=1}^{m,n} (X_{i,j-h} - X_{i,j})^2$
   
   End if and
   
   If row $i$ is greater than distance $h$ then
   
   $\text{SumV} = \sum_{j=1}^{m,n} (X_{i,h-j} - X_{i,j})^2$

8. Compute horizontal and vertical semivariance for each range $\text{SumH}(h) = (1/2 \times \text{Hpair}) \times \text{SumH}$ and $\text{SumV}(h) = (1/2 \times \text{Vpair}) \times \text{SumV}$ respectively.

9. If sill point is not achieved then go step 3
10. Plot the taking log of distance $h$ and log of horizontal and vertical semivariance
11. Determine the slope.
12. Compute vertical and horizontal fractal dimension $FD = 4 - \text{slope}/2$
13. Compute the average of vertical and horizontal fractal dimension

IV. RESULTS DISCUSSION

The research work carried out presented in form of visualization graphics simulation result for non glaucoma and glaucoma in this section. The figure 3 and figure 4 shows the result of non glaucoma image and found the fractal dimension in the range of 1.59 to 1.85 which maps universally accepted result of mean fractal dimension (1.84). Figure6 and figure7 shows the result of glaucoma image and found the fractal dimension in the range of 1.39 to 1.59. The figure5 and figure8 describe the detail simulation result for obtaining fractal dimension for non glaucoma and glaucoma. Figure5 (a),(b) and (c) shows the non glaucoma image input image that is converted into gray level and extracted region of interest (optic disk) respectively. Figure 5 (D) shows horizontal fractal dimension 1.65 (red) and vertical fractal dimension1.58 (blue) finally taken mean of the horizontal and vertical fractal dimension (1.62). In fig8 (a),(b) and (c) same as description of fig5 (A),(B), (C) and fig8 (D) shows horizontal fractal dimension 1.35 (red) and vertical fractal dimension1.42 (blue) finally taken mean of the horizontal and vertical fractal dimension (1.39).

Glaucoma images are very smooth compared to non glaucoma images it mean gray level intensity of non glaucoma image almost equal so semivariance values are less in variance over the distance $h$ therefore the slope is smooth (less) the author observed fractal dimension is inversely proportionally to slope then definitely fractal dimension larger as Medle Brot say. Glaucoma image more rough and irregular it mean intensity of gray level more varies so semivariance values greater in variance therefore slope is very strip definitely fractal dimension less. The fig9 depicts the average (horizontal and vertical) fractal dimension of glaucoma and non glaucoma is 1.51 and 1.64 respectively. The author is observed for non glaucoma image slope is smooth hence the fractal dimension greater and for glaucoma image slope is steep therefore fractal dimension lesser.
V. CONCLUSION

This paper presents the state of art for earlier detection of glaucoma using image analysis through with extraction of region of interest (optic disk) and estimation of fractal dimension using semivariance method. Sill or optimum point is obtained by raising distance $h$ once sill or optimum point is reached then computed the fractal dimension by computing slope for horizontal and vertical direction. In this work fractal dimension found for glaucoma and non glaucoma in the range of 1.39 to 1.58 and 1.59 up to 1.85 respectively. Future is kept for extracting optic disk as a square image to provide the equal opportunity for horizontal and vertical direction.

REFERENCE


