Retina Recognition Based on Fractal Dimension

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Abstract

The recent advanced developments in the research have enabled the industries to find more complex methodologies for personal authentication. This led to the high development in the area of biometrics for the research of the retina recognition which is more complex and accurate for the authentication. The retinal circulation of the normal human is statistically self-similar and fractal. The survey study shows strong evidence that the fractal dimension of the blood vessels in the normal human retina is approximately 1.7. This paper contributes the methodology for the retina recognition for enhanced authentication biometric technique from the experimental results. The main objective of this study is to assess the accuracy of a commercially available retina biometric technology for personal identification on high security basis.

Keywords – Retina Recognition, Fractal Dimension, Enhanced Box counting.

1. Introduction

The biometric authentication is a technology that measures and analyzes human physical and behavioral characteristics for recognition and authentication purposes for security and personal identification [3]. The main advantage of the biometric technology is that, it would be more secure, safe and comfortable than the other security systems like usage of password and tokens.

There are many biometric technologies for the authentication purpose but still many of the technologies faces a strong crash for its recognition because of the variation that occur [4]. For example in face recognition, the difficulties arise from the fact that the face is a changeable social organ displaying a variety of expressions, image varies with viewing angle, pose, illumination, and the accoutrements, and age. The study shows that the facial images taken at least one year apart, even the best current algorithms have error rates of 43% [7 and 8] to 50% [9]. To overcome the above and many other problems the best methodology can be used is retina based biometric technology for the authentication to be more accurate and secure as it does not variant and provide a permanent and unique personal identification. The retina of a normal human though small (11 mm) and sometimes problematic to image, it has the great mathematical advantage that its pattern variability among different persons is enormous. It is an internal (yet externally visible) organ of the eye, the retina is well protected from the environment, and stable over time [6].

The paper is organized as follows. The next section describes the fundamentals of fractals, followed by the section describing the evaluation of fractal dimension and its methods for recognition using box counting algorithm. The section 4 presents the experimental results conducted and the discussions made. The last section discusses the conclusion derived.

2. Fractal and Fractal Dimension

Fractals are of rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced copy of the whole. They are crinkly objects that defy conventional measures, such as length and are most often characterized by their fractal dimension. A fractal dataset is known by its characteristic of being self-similar. The dataset has roughly the same properties for a wide variation in scale or size i.e., parts of any size of the fractal are almost similar to the whole fractal [12]. Intuitively, a set of points which exhibit self similarity over all scales fractals are crinkly objects that defy conventional measures, such as length and area, and are most often characterized by their fractional dimension [10 and 11].

The fractal dimension is a statistical quantity which gives the indication of how completely the fractal appears as it is zoomed down to finer and finer scales. Fractal dimension measures the degree of fractal boundary fragmentation or irregularity over multiple scales. It determines how fractal differs from Euclidean objects (point, line, plane, circle etc.).

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Fractal dimension is an effective measure for complex objects. It is widely applied in the fields of image segmentation and shape recognition. The fractal dimension can be any non-negative real number and can be estimated in several ways [5]. The basic idea of the fractals is illustrated in the below figure 1, steps to build the Sierpinsky triangle, which is one of the well-known point-set fractal.

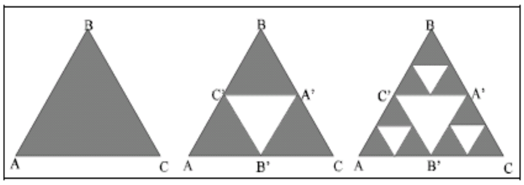

Figure 1 Sierpinsky Triangle

The above figure 1 shows the Sierpinsky triangle which is constructed from an equilateral triangle ABC, excluding its middle triangle A'B'C' and this procedure is recursively repeated for each of the resulting smaller triangles. This is generated after infinite iterations of this same procedure. The Sierpinsky triangle has an infinite perimeter, and hence it is not a 1-dimensional object. This also does not have any area, so it is not a 2-dimensional object. In fact, the above figure 1 is an intrinsic dimension, equal to log 3/log 2=1.58 [13]. For a real set of points, we measure the fractal dimension with the box-count plot, which is the basis of the algorithm to be proposed in Section 3. The correlation dimension is the measure of dimensionality of the space occupied by a set of random points, a type a of fractal dimension [15]. The Minkowski dimension or box-counting dimension is a way of determining the fractal dimension in a set in a Euclidean space, or generally in a metric space.

3. Feature Extraction and Classification

There are many ways to evaluate the fractal dimensions, such as Fractional Brownian Motion, Hausdroff Besicovitch dimension and many but they are calculated complicated and the computational cost is very high.

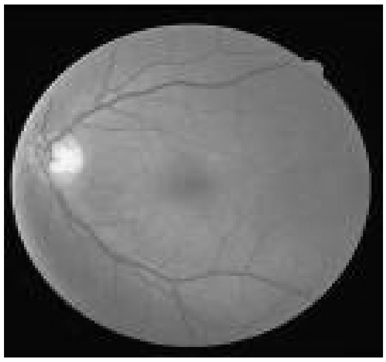

Fig 2 (a) Retinal image

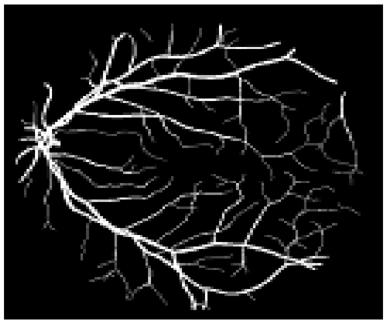

Fig 2 (b) Retinal vascular tree

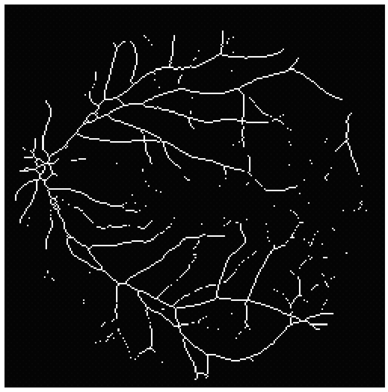

Fig 2 (c) Retina Features

Figure 2 Blood Vessels for Retina

The advantages of retina are low occurrence of false positives, extremely low (almost 0%) false negative rates, highly reliable because no two people have the same retinal pattern, Speedy results, Identity of the subject is verified very quickly. The retina has unique blood vessels as shown in figure 2(b) which could recognize unique authentication and figure 2(c). shows the feature extraction of the retina.

3.1 Enhanced Correlation based Box Counting Algorithm

The following gives a brief explanation of the salient features of the method used for computing the fractal dimensions using Box Counting Algorithm. It incurs only O(N) computational cost [16]. This algorithm derives its name from the imposition of nested hypercube grids over the data, followed by counting the occupancy of each grid cell [14], thus the focus will been the individual points instead of on pairs. By substituting these counts for the pair counts in the same power law relationship which estimates, the fractal dimension. Given sufficient space to store all the counters simultaneously, all counts can be computed in a single pass over the data. Thus the algorithm provides a greater efficiency.

Considering the solid fractal object only a finite resolution is available so the limit *r* -> 0 cannot be taken into consideration. The retina is considered as the fractal object. A natural and direct approximation is just to apply directly but with the smallest *r* available. That is,

$$D_o \approx \log [l/n(r)] / \log r$$

The most common problem with this estimation is that it converges with logarithmic slowness in *r*. For instance, $n(r) = n_o r^{-Do}$ will give

$$\log [(1/no)\, r^{Do}] / \log r = D_o \log r + \log (1/n_o) / \log r$$
$$= D_o + \log (1/no) \approx D_o.$$

Instead, log *n(r)* versus log *r* is usually plotted for better results. The negative slope of this curve will give D_o for small *r:*

$$D_o \approx -\Delta\ [(\log n(r)] / \Delta(\log r)$$

The principle for choosing the best slope for the fractal estimation for retina recognition is thus done by which it saves a lot of computational cost and time [17].

3.2 Evaluating Correlation Fractal Dimension of Fractal Image

In order to take the full advantages of the 2D information of the retina, retina image is divided into many small regions and H_i (i=1, 2, 3 …) of each region is calculated, so fractal feature of whole image can be presented $H = (H_1, H_2…, H_n)$.

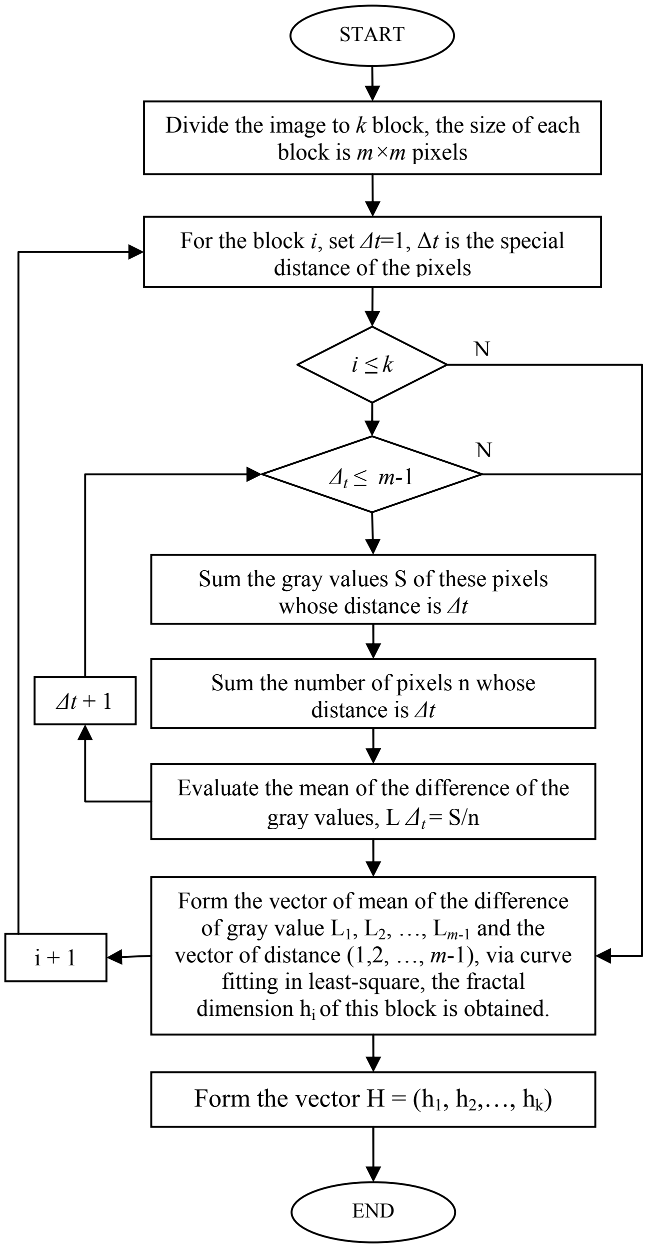

Figure 3. Flowchart of Evaluating Fractal Dimension

3.3 Retina Recognition

The robust representations for recognition must be invariant to changes in the size, position, and orientation of the patterns. In the case of retina recognition, it creates a representation that is invariant to the optical size of the iris in the image the size of the retina the location of the retina within the image and the retina orientation. The figure 2 shows the sample retina recognition. Fortunately, invariance to all of these factors can readily be achieved and hence this overcomes all the above drawbacks which are present in most other authentication techniques used in biometrics. The blood vessel pattern of the retina does not or rarely changes during a person's life. The retina size of the actual template is only 96 bytes, which is very small by any standards. In turn, verification and identification processing times are much shorter than they are for larger files. The rich, unique structure of the blood vessel pattern of the retina allows up to 400 data points to be created.

4. Experimental Results and Discussion

There are numerous methodologies for the estimation of the correlation fractal dimension. But they are done by the redundant rescans which implies that these are not efficient time and space management. The box counting algorithm scans the dataset and provides better efficiency and more accuracy than the other algorithms.

4.1 Experiments on Enhanced Correlation Based Box Counting Algorithm

Experiments were conducted on different retina identification for the authentication purpose and the images of these retinas are considered as the results of feature extraction of the correlation fractal dimensions using Enhanced Correlation Based Box Counting Algorithm. The ones that were not used to training were used to testing.

Ten different training and testing images were applied to retina recognition and the average rate is calculated. Each input was resized into small scale with bilinear interpolation for decreasing data, and then it was divided into non overlapping blocks. The choice of resized scale of the image and the size of the blocks affect the retina recognition rate. Nine kinds of resized retina images were taken into experiments because these blocks were non - overlapping. Some of these resized images were small scale and could only be divided into single size. The other bigger scale images could be divided into double size.

The results from the below graph shows a significant improvement in the accuracy of retina recognition when the image is resized into 28×24 and divided into 4×4 blocks it produces 93%, with best recognition rate. In the process of experimental results, the better recognition rates were achieved 96%. The better recognition rates and the comparison of the two methods are represented in the following graph.

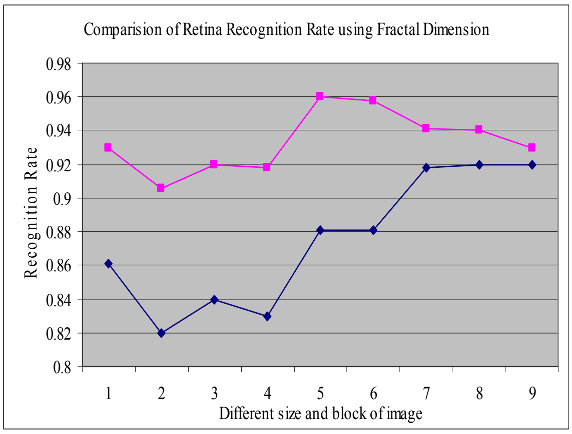

Figure 4. Recognition Rate Vs Block size

4.2 Experiments on Drive Retina Database

The retina recognition was performed without further histogram and with illumination varied widely from centre lighting to left lighting and right lighting. Some of the images were used for training and the others were used for testing. According to the box counting algorithm the best results that were achieved from the new fractal dimension is got when the image is 64×64 with block 8×8, the experiments were carried out with resized to 56×56 and divided into blocks of 8×8, in additional many experiments were done with all kinds of distance.

The results are shown in Figure 4. The best recognition rate achieved is 98.33%. The average recognition rate that was obtained using fractal dimension and the box counting algorithm are compared with other systems and the results are shown in the table below.

Method	Recognition Rate	Classification Times(s)
Fractal Dimension using Box Counting	94.33%	3.7
Fractal Dimension using Enhanced Box Counting	98.33%	3.1

Table 1: Comparisons of the results with other systems

The retina recognition rate obtained was 94.25% when 5 samples of retina were used and 40 Eigen samples were used for the basis of Eigen pictures. Using 2 samples of images for training, the method of fractal dimension and the genetic algorithms achieved with retina recognition rate of 93.25%.

5. Conclusion

This paper presents an approach towards the retina recognition method based on fractal dimension using box counting algorithm. The fractal dimension found to produce best results for the feature extraction for retina recognition, for its efficient representation of 93.25% on the box counting database while some of the images were used for training and the other were used for the testing. This paper also produces the best retina recognition results with 96% by finding new fractal feature. From the experimental results of retina recognition, the verification and identification processing times are much shorter than they are for larger files and produces better accuracy, less computational cost and the core point is that the criteria (retina) is invariant which would produce the best results for personal authentication.

Acknowledgement

A public version of the Retina DRIVE: Digital Retinal Images for Vessel Extraction is available from http://www.isi.uu.n/Research/Databases/DRIVE

References

[1] M. Schroeder, Fractals, Chaos, Power Laws, 6 Ed. New York: W.H. Freeman and Company, 2006.

[2] Belussi and C. Faloutsos, Estimating the Selectivity of Spatial Queries Using the ‘Correlation’ Fractal Dimension, in: Proc VLDB, Zurich, Switzerland, September 2005.

[3] Daugman, J. High confidence visual recognition of persons by a test of statistical independence Trans. Pattern Analysis and Machine Intelligence, 2003

[4] Daugman, J. U.S. Patent No. 5,291,560: Biometric Personal Identification System Based on Retina Analysis. Issue Date: 1 March 1994.

[5] Daugman J. Statistical richness of visual phase information: Update on recognizing persons by their retina patterns. International Journal of Computer Vision 2001.

[6] Daugman, J., and Downing, C. Demodulation, predictive coding, and spatial vision. Journal of the Optical Society of America, 2005.

[7] Pentland, A., and Choudhury, T. Face recognition for smart environments. Computer 33(2): 50-55, 2000.

[8] Phillips, P.J., Martin, A., Wilson, C.L., and Przybocki, M. An introduction to evaluating biometric systems. Computer 33(2): 56-63. 2000.

[9] Phillips, P.J., Moon, H., Rizvi, S.A., and Rauss, P.J. The FERET evaluation methodology for face-recognition algorithms. Trans. Pat. Anal. Mach. Intel. 22(10): 1090-1104, 2000.

[10] Daugman, J., and Downing, C. Epigenetic randomness, complexity, and singularity of human face patterns. Proceedings of the Royal Society, Biological Sciences 268: 1737-1740, 2001

[11] Kronfeld, P. Gross anatomy and embryology of the e ye. In: The Eye (H. Davson, Ed.) Academic Press: London, 2002.

[12] Pentland, A., and Choudhury, T. Face recognition for smart environments. Computer 33(2): 50-55, 2000.

[13] Phillips, P.J., Martin, A., Wilson, C.L., and Przybocki, M. An introduction to evaluating biometric systems. Computer 33(2): 56-63, 2000.

[14] Simon, A., Worthen, D.M., and Mitas, J.A. An evaluation of iridology. Journal of the American Medical Association 242: 1385-1387, 2007.

[15] A. Wong, L. Wu, P.B. Gibbons, and C. Faloutsos, “Fast estimation of fractal dimension and correlation integral on stream data”, Information Processing Letters, vol. 93, pp. 91-97, 2005.

[16] H. S. Greenside, A. Wolf, J. Swift, and T. Pignataro, "Impracticality of a box-counting algorithm for calculating the dimensionality of strange attractors," Phys. Rev. 25, 3453, 2002.

[17] “Practical implementation of the box counting algorithm", Guido Gonzato. Dipartimento di Fisica, Settore di Geofisica, Università di Bologna, Viale Berti Pichat 8, 40100 Bologna, Italy, 2008.