APLICATION OF FRACTAL DIMENSION ESTIMATION ALGORITMS TO EVALUATING HUMAN SKIN STATE

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ABSTRACT

Fractal dimension has been used for texture analysis as it is highly correlated with human perception of surface roughness and applied to quantifying the structures of wide range of objects in biology and medicine. On the other hand, the evaluation of the human skin state is based solely on the subjective assessment of clinicians; this assessment may vary from moment to moment and from rater to rater. Therefore we attempt to analysis of skin texture image using fractal dimension and discuss its application to evaluating human skin state. It can be helpful for extracting human features and also can be useful for detection of many human skin diseases. This paper presents a method to calculate fractal dimension of skin with use of camera lens magnification. We take multiple pictures frequently from skin with different camera lens magnification as a magnification factor of fractal set, and counting the number of objects (cells) in each picture as a number of self similar pieces of fractal set.

Keywords: Fractal dimension, skin, gender, lens magnification

1. Introduction

Recently numbers of applications based on the ability of extract human information from images are increase. Estimation of gender and age can give valuable information for evaluation of man-machine interfaces such as person identification for surveillance or access control.

On the other hand, the use of images to help formulate or represent mathematical concepts is littered with the efforts of mathematicians who, using the technology of the time, have attempted to represent mathematical concepts in terms of a figure or image or even a physical model. On the contrary, in image processing we use this technology to represent image in terms of mathematical concepts.

Among of these concepts, the application of Fractal geometry to imaging science and hence computer vision is now receiving serious attention.

Fractal dimension is an important parameter that can be used in various applications such as surface roughness estimation, estimation of roughness in an image, image compression, image segmentation and many others.

There is a lot of work to estimate age and gender from image based on facial expression and also a lot of work to extract human features based on fractal dimension but this is a new effort to extract human features based on fractal dimension of skin image according to skin texture.

Results of previous experiments illustrated the texture of the skin can represent by fractal dimension of skin surface image, calculated by Box-counting method. And represent better by fractal dimension of skin image calculated by Power spectrum method [1], [2].

But aim to achieve accurate estimation of human skin state based on fractal dimension, this paper presents a method to calculate fractal dimension of human skin directly from human skin instead of human skin image.

To directly calculating the fractal dimension of skin surface instead of calculating fractal dimension of skin from skin image. And according to fractal dimension definition, we use different camera lens magnification as a magnification factor of fractal set (Skin) and count the objects (Cells) number of each picture taken by different magnification lens, as number of self-similar pieces of fractal set.

This paper presents a method to compute fractal dimension of fractal surface, through multiple pictures taken frequently from fractal surface with different camera lens magnification and apply it to calculate fractal dimension of human skin to extract human features such as gender.

2. Methods to calculate Fractal dimension of skin

In previous research for analysis of human skin texture image we used fractal dimension and discussed its application to evaluate human skin state, we attended to two models for computing fractal dimension of human skin image for extract human features. These models are: i) Box counting and ii) Power spectrum.

At first, we took a picture from the inner forearm of hand of people with an USB-microscope camera at 50 times magnification. Then, we prepared a grayscale image for each picture. And finally we calculated fractal dimension of each grayscale image using Box counting and Power Spectrum methods.

The behavior of these algorithms are such that the greater the number of pixel, And the greater the difference in gray level, the better the estimate of the fractal dimension but because of resolution limited of each image, results of algorithms cannot be well.

Note: we calculated fractal dimension of skin from one picture of skin.

2.1 Application of camera lens magnification for calculate Fractal dimension of skin

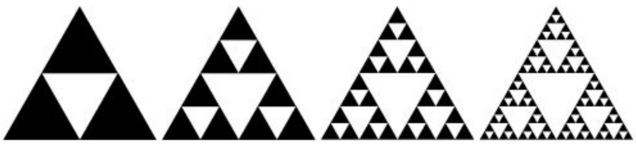
To provide more accurate estimation of skin state, we need to calculate accurate fractal dimension of skin, therefore we try to calculate fractal dimension of skin directly from skin surface instead of calculate fractal dimension of skin from skin image.

Aim to directly calculating fractal dimension of skin surface, we use camera magnification lens as a magnification factor and take picture frequently from skin by changing the lens magnification from high to low.

Then we count the number of objects (cells) in each picture taken with different magnification lens as a number of self similar pieces of skin fractal set.

By taking pictures with different lens from skin we are able to take more information from skin and consequently obtain skin fractal structure and have more accurate fractal dimension.

Foundation of fractal geometry is the concept of self similarity. Fractal surface is including repeated structure at all scales. Each subsequent magnification reveals ever more fine structure. As shown in Figure (1) the set *A* is said to be self similar if *A* is in the union of N distinct copies of itself, each of which has been scaled down by a ratio r < 1 in all coordinates[3].



$r = 1/2$ $\quad r = 1/4$ $\quad r = 1/8$ $\quad r = 1/16$

$N(r) = 3$ $\quad N(r) = 9$ $\quad N = 27$ $\quad N(r) = 81$

Fig. 1: Sierpinski Triangle. Number vs. lengthy scale

However, natural fractals do not in general possess such deterministic self similarity. Therefore, a magnified section of skin will resemble the whole in some way but not exactly. The skin exhibits statistical self similarity. Such fractal sets are composed of N distinct subsets each of which is scaled down by a ratio r <1 from the original and is identical in all statistical respects to the scaled original.

For calculating more accurate fractal dimension of skin we apply fractal dimension definition. Then

$$D = -\lim_{r \to 0} \frac{Ln\, N(r)}{Ln\, r} \quad (1)$$

where N(r) is number of Cells (self similar pieces) with magnification factor r, and r is Camera lens magnification (magnification factor) ,D is skin fractal dimension.

Note that in the most of fractal dimension calculator algorithms, to calculate fractal dimension of a fractal sets, just one picture of fractal sets is applied. And most techniques are based on recursive length or area measurements of a curve or surface using different measuring scales. Consider a simple straight line over which scales a shorter line.

In suggested method we used different picture taken from fractal set by different lens magnification as shown in Figure 2 to Figure 5. Consider a diameter over which scales a shorter diameter. Consequently we are able to obtain more accurate structure of fractal and then more accurate fractal dimension.

2.1.1 The Least Squares Approximation

In this technique, we look for the best straight line fit through a set of data point.

For computing the fractal dimension of skin, we use the logarithmic plots to fit results of Equation (1) to a line. And we are interested in finding the slope β of this line.

The slope β obtained in a bilogarithmic plot of the number of objects in skin pictures (cells) used against the camera lens magnification applied for take that skin picture. Then gives the fractal dimension of skin where

$$D = -\beta \quad (2)$$

2.1.2 Counting the number of objects in an image

For counting the number of objects (Cells) in each picture we need to have a clear border between cells. Therefore we apply a highpass filtering to achieve a sharp edge in grayscale image of each picture. Highpass filtering sharpens the image by attenuating the low frequencies and leaving the high frequencies of the Fourier transform relatively unchanged.

Then we generate binary image from sharpened edge grayscale image. In binary image, pixels that are “on”, i.e., set to the value 1, are considered to be the foreground. The foreground pixels appear white. Pixels that are “off”, i.e., set to the value 0, are considered to be the background. The background pixels appear black.So in binary image, with labeling the connected component that those values are 1 in each image, we are able to identify each object.

The pixels labeled 0 are the background. The pixels labeled 1 make up first object, the pixels labeled 2 make up a second object, the pixels labeled 3 make up third, and so on[4].

3. Experiment and results

For consideration the ability of fractal dimension as a skin state evaluation, and for survey on accuracy of explained method, we applied this method for calculating fractal dimension of human skin surface as an estimation of human skin roughness and also as an extraction of human gender.

For examining gender features, 10 healthy Japanese subject participated in an experiment, consisting of 5 young men and 5 young women.

In this experiment to take picture from the skin of subjects, we used a Digital microscope camera with a changeable lens magnification. Pictures taken by this camera are JPEG truecolor image.

At first we took a picture from inner forearm skin surface of each subject by a camera lens at 200 time magnification. Then we generated a grayscale image for that picture as shown in Figure 2.

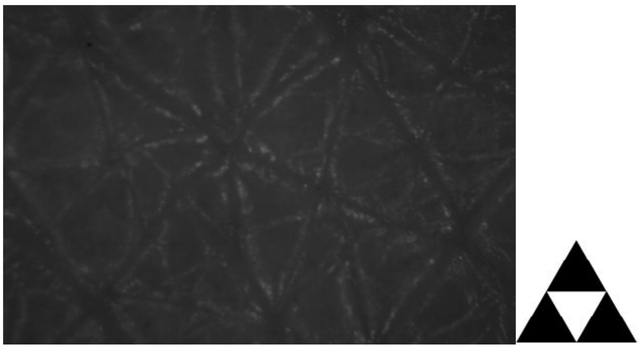


Fig. 2: Skin grayscale image taken by X200 magnification lens comparable with Sierpinski Triangle when r=0.5

Secondly we took a picture from same place of inner forearm skin surface of each subject by a camera lens at 150 time magnification and generated a grayscale image from that picture as shown in Figure 3.

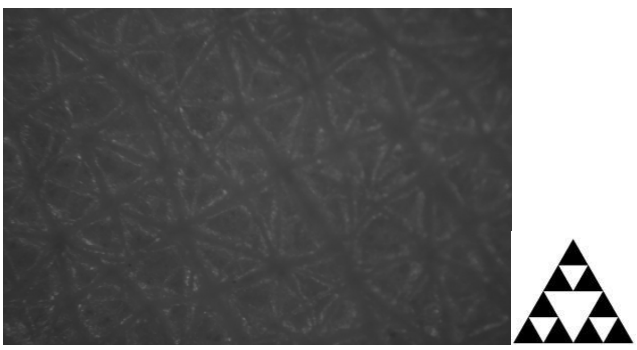


Fig.3 Skin grayscale image taken by X150 magnification lens comparable with Sierpinski Triangle when r=0.25

Thirdly we took a picture from same place of inner forearm skin surface of each subject with camera lens in 100 time magnification and generated a grayscale image from that picture as shown in Figure 4.

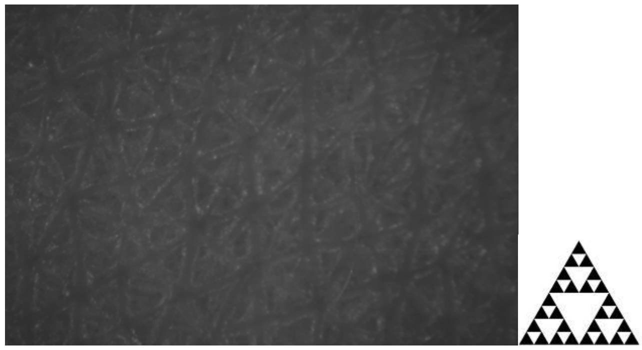


Fig. 4: Skin grayscale image taken by X100 magnification lens comparable with Sierinski Triangle when r=0.125

And fourthly we took a picture from same place of inner forearm skin of each subject by a camera lens at 50 time magnification and generated a grayscale image as shown in Figure 5.

Fig. 5: Skin grayscale image taken by X50 magnification lens comparable with Sierinskin Triangle when r=0.0625

In the second step, as it was explained in Section 2.1.2 for counting the number of objects (Cells) in each picture, we need to have a clear border between cells. Therefore we applied a highpass filter to achieve a sharp edge between cells.

Then we generate binary image from highpass filtered grayscale image. Figure 6 shows a binary image, generated from grayscale image after sharpness filtering from picture taken by a camera lens in 50 time magnification.

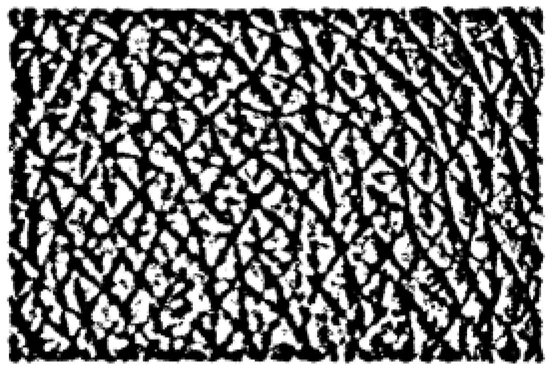


Fig. 6 Binary image generated from grayscale image after highpass filtering taken by X50 magnification lens

In this binary image we consider the white area as self similar pieces of skin fractal. However, natural fractals do not in general possess such deterministic self similarity. Therefore, a magnified section of skin will resemble the whole in some way but not exactly.

As it was explained in Section 2.1.2, in binary image, with labeling the connected component that those values are 1 in each image, we are able to identify each object.

The pixels labeled 0 are the background. The pixels labeled 1 make up first object the pixels labeled 2 make up a second object, the pixels labeled 3 make up third, and so on. So we find the number of self similar pieces of fractal set.

Finally as explained in Section 2.1.1 and from Equation (1) and Equation (2), a classical algorithm for estimation of fractal dimension D as shows in Figure 7, calculation of slope of the plot of Ln N(r) and Ln r, where N(r) is number of self similar pieces (cells) in each image taken by different camera lens magnification and r is camera lens magnification, gives us a simple algorithm for the value obtained from skin fractal set.

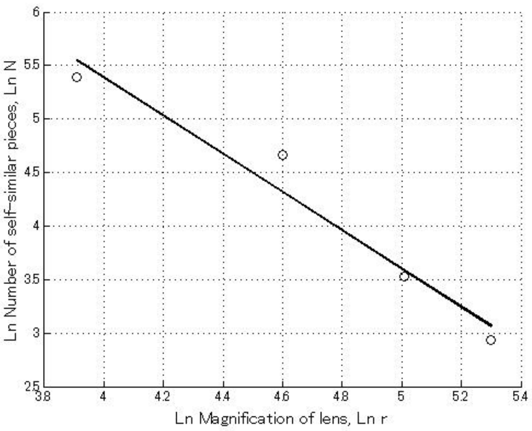


Fig.7: Plot (Ln Number of self similar pieces vs. Ln Camera lens magnification)

Figure 8 shows the results of experiment and illustrated the fractal dimension of young women are between 1.8 and 1.9 when fractal dimension of young men are between 1.7 and 1.8 and according to graph we are able to extract human gender by computing fractal dimension of human skin.

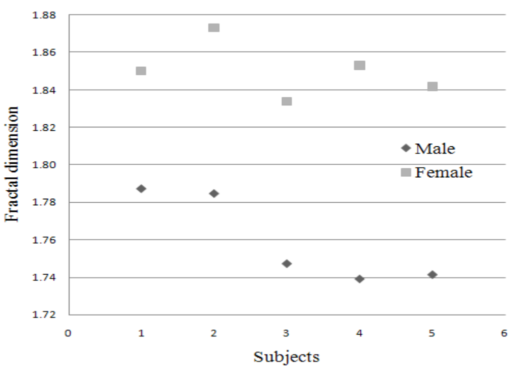


Fig. 8 Fractal dimension of inner forearm skin surface from 5 young female and 5 young men computed by explained method

4. Conclusion

Skin is the largest part of human body and is a good exhibition of human condition. So provide a good estimation of skin can be helpful in many cases such as human machine relation, security, medical science and etc.

To extract human skin condition, we estimate fractal dimension of human skin with common algorithms of calculate fractal dimension from human skin surface image. But to provide accurate estimation of skin, this paper presents a method to estimate a fractal dimension of skin directly from skin surface instead of estimate fractal dimension of skin from skin image. In this method we apply camera lens magnification as a magnification factor of skin fractal set and take multiple pictures frequently from skin by changing the camera lens magnification. Then we count the number of objects in each image as a number of self similar pieces of fractal set. Then according to fractal dimension definition we are able to simple algorithm to estimate of fractal dimension of human skin. In this method by apply a multiple image we are able to achieve more information from fractal set of skin and consequently have accurate estimation of fractal dimension of skin.

According to results of experiment, fractal dimension of skin of young women is higher than fractal dimension of skin of young men and it's useful to apply as a gender extraction. One possible reason for this difference is the difference of skin cells size in men and women, caused by the value of collagen and consequently the numbers of cells are different in each scaled image. Results of experiment illustrated that the skin texture can be represented by fractal dimension of skin.

Acknowledgment

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5. REFERENCES

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