Detection of Osteoporosis Using Fractal Method Based on Fourier Analysis of Hand Bone Image

Nurhasanah¹, J Sampurno¹, O Ivansyah²

¹Department of Physics, Tanjungpura University, Indonesia, 78124
²Politeknik Negeri Pontianak, Indonesia, 78124

*nurhasanah@physics.untan.ac.id

Abstract. This study applies the method of fractal-based 2D Fourier transform to determine an image of osteoporosis or normal based on the dimensions and intercept of the X ray image hand bones. The first step is to create a program to determine the dimensions and the intercept of image. It is determined by using a fractal method based on 2D Fourier transform. Testing the success of the program is done by input X ray image of the hand bones. The result shows that the program testing 2D Fourier transforms can be applied to determine the dimensions and intercept of the hand bones image. The classification of the normal and osteoporosis images is based on the dimensions and intercept values. Normal image has dimension <1.4 and intercept value >34, osteoporosis image has dimension >1.4 and intercept value <34. Dimensional of osteoporosis image have higher than normal image but the normal image density is higher than the osteoporosis image. Classification results quite effectively to help diagnose osteoporosis.

1. Introduction

The diagnosis of disease can be done through medical image analysis without surgery. For example, x-ray image of bone is used to determine bone structure abnormality and human bone dysfunction. This abnormality can be used to determine an osteoporosis.

Osteoporosis is a bone condition which are characterized by low bone mass, increased brittleness, decreased bone quality and increased risk of fractures [1]. This disease has a significant impact on morbidity and mortality [2] and the disease has a significant impact on morbidity and mortality and poses/becoming a threat to health problems around 200 million people in the world [3]. In the previous work, bone image analysis for osteoporosis identification has been developed using discriminant analysis methods [4] and artificial neural network method [5, 6].

Fractal analysis method is one of the pattern-based methods that have been used extensively in the field of health. This method has been used in previous studies such as: cancer analyzed [7], analyzing of data radiographic of trabecular tissue texture [8], human brain analyzed [9], analyzing the dynamics of the heart rate of young people affected by metabolic syndrome [10] and breast cancer analyzed [11]. This method is considered better to analyze the tissue and has high precision.

In this paper, we proposed a new method based on the fractal analysis that used to characterize osteoporosis. The purpose of the research is to increase the objectivity of clinical diagnostic by applying the fractal method on the bone x-ray images. In this method, the images data, which in spatial domain, was transformed to the frequency domain using Fourier Transformation. The parameters which are used to characterize the osteoporosis are Fractal dimension and intercept.
2. Experimental details

2.1. Pre-processing

The data which are used in this study is X-Ray images of normal hand bone and osteoporosis hand bone (figure 1a and figure 1b). Before analysis, the data were prepared using image processing procedure. Image processing procedure starts with pre-processing. The aim of the pre-processing is to improve the quality of the image in order to make it is easier to be processed and to be analyzed further. The pre-processing consists of cropping the Region of Interest (ROI), grayscalling and equalization to improve the image contrast. The results of the process can be seen in the figure 1a and figure 1b.

![Figure 1](image1.png)

**Figure 1.** (a) Normal hand bones; (b) Osteoporosis hand bones

The next process is a fractal analysis method based on 2D Fourier transformation and classification of image based on the fractal dimension and intercept.

2.2. Fractal analysis

Fractal Analysis Some text was conducted to obtain the dimension and the intercept of the image. In this method, the distribution of image pixel values in the spatial domain was transformed into the frequency domain.

Horizontal surface characterization is represented by fractal dimension parameters. Fractal dimension is a complex geometry quantification tool. Determination of fractal dimension in 2D image (2D) can be done based on Fourier analysis. The pixel distribution in the 2D image in the spatial domain is transformed into the frequency domain. Image transformation is represented in the Fourier domain, where each point represents the frequency of particles [12,13]. Fourier analysis on fractal space has been used for image identification [14].

The vertical characterization of the 2D image represented by topothesy parameters and intercept parameters. Intercept is the curve intersection of the log axis (magnitude) plotted to the log (frequency) of the fourier analysis method [15]. The intercept value represents the density contrast value between one point and the other point distributed throughout the image.

The transformation from the spacial domain to the frequency domain can be achieved by Fourier transform to handle all aspects of images. However, this type of transform has a wide range of applications in image processing. Any general periodic signal has the automatic property [16].
\[ f(t) = f\left(\frac{2\pi t}{T}\right) \]  

(1)

where \( T \) is the period of the signal. The \( 2\pi \) is placed in due to the fact that trigonometric functions are good examples of repetition. The Fourier transform in 2D for \( f(x,y) \), is defined as,

\[ F(u,v) = \iint f(x,y)e^{-j2\pi(u\Delta x+v\Delta y)}
\]

\[ \times dx\,dy \]

(2)

while, the 2D Discrete Fourier Transform with \( x = 0, ..., N - 1 \), and \( y = 0, ..., M - 1 \), is defined as:

\[ F(u,v) = \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} f(x,y)e^{-j2\pi\left(\frac{ux}{N} + \frac{vy}{M}\right)} \]

(3)

where, \( u = 0,1,2, ..., N - 1 \) and \( v = 0,1,2, ..., M - 1 \)

The Inverse Discrete Fourier Transform (IDFT) is defined as:

\[ f(u,v) = \frac{1}{NM} \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} F(u,v)e^{j2\pi\left(\frac{ux}{N} + \frac{vy}{M}\right)} \]

(4)

where, \( x = 0,1,2, ..., N - 1 \) and \( y = 0,1,2, ..., M - 1 \)

This transformation was to get the Power Spectra Density (PSD) of this spatial data. If the image behaves as fractal, the plot of log (magnitude²) vs. log (frequency) will generate a linear curve. This curve has a slope and a point of intersection on the y-axis. Fractal dimension was obtained from the slope of the curve. Intercept value was obtained from the point of intersection on the y-axis. Image fractal dimension calculated from the slope of the equation [1].

\[ D = \frac{6 + \beta}{2} \]

(5)

where \( D \) is the fractal dimension and \( \beta \) is the slope value.

The classification is done by analyzing the X-ray image of the hand bones based on the dimensions and grades interpret the image.

3. Results and Discussion

3.1. Fractal analysis

Fractal analysis based on 2D Fourier transformation can produce fractal dimensions and intercept of each sample. The fractal dimension and the intercept of each sample are shown in Table 1. The fractal dimension describes how roughness changes with scale and the intercept value represents the density contrast between points to other points which is distributed throughout the image.

It can be seen from Table 1 that all fractal parameters for normal bone are distributed. In the first place, the highest Fractal Dimension for normal bone is 1.448956, while the lowest is 1.275454. Moreover, Intercepts of this category are spread between 34.27002 and 35.5038. Table 2 shows the distribution of Fractal’s parameters for osteoporosis bone. Firstly, the highest Fractal Dimension for osteoporosis bone is 1.606436, while the lowest is 1.437109. Furthermore, Intercepts of this category expand from 32.18103 to 33.70687.
We can obtain the relation between Dimension and Intercept as shown in figure 2. The classification result shows that osteoporosis hand bones image is represented by the high fractal dimension (>1.43) and low intercept value (<34) and vice versa (figure 2).
4. Conclusion
The fractal method based on Fourier 2D analysis plays an important role in several image processing
techniques. In this paper, a new view point to analysis in fractal space of hand bone image is proposed.
A novel approach to estimate fractal dimension and intercept of hand bone image. The results of this
study concluded that the fractal method based on Fourier 2D can be used to distinguish normal and
osteoporosis hand bones images.

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