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# Classification of Gamelan Tones Based on Fractal Analysis

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6

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**Abstract.** Gamelan is an ensemble music originated from Indonesia. Gamelan have been made manually but had 7 tonnes for Pelog scale or 5 tonnes for Slendro scale. It is need to classify gamelan tones for digital musical processing for various objectives like learning, teaching, or composing. Fractal analysis can be used to classify physical phenomenon like musical tones signal. One of fractal method was Higuchi that is suitable in computing fractal dimension for time series data as musical signals. In this paper, we propose the Higuchi fractal dimension to distinguish gamelan signal tones. Our experiment show that Demung Pelog tones can be classified properly until 82.85%. This result encourages to classify gamelan tones not only for other instruments but also for Slendro scale.

## 1. Introduction

Gamelan is one of the traditional ensemble music from Indonesia that known worldwide. Although gamelan has been made since the 3rd century [1]. It has a scale similar to modern music. In Javanese gamelan there are two scales namely Pelog consisting of 7 tones and Slendro which consists of 5 tones. The making manually gamelan resulted in many variations on the produced sound. Thus, required the classification of gamelan tones.

The classifications of musical tones are important in digital musical processing. Musical tone is a medium for playing someone's work on music. Briefly speaking, musical notation is a language among musicians to learning, teaching, or composing [2]. Writing a musical notation is a hard work except for a musical expert. In this case, it is necessary to classify tones from a musical notation.

The work on musical tones classification were done by some researchers. Instrument identification in musical recordings use Independent Subspace Analysis (ISA) [3]. Ozbek, Delpha, and Duhamel [4] use Likelihood-Frequency-Time (LiFT) and Support Vector Machines (SVM) to classify 36 notes of 19 instruments. Macedonian traditional music using the Minkowski-Bouligand fractal dimension [5]. Piano notes using Digital Signal Processing (DSP) [2]. Recently Reljin and Pokrajac classify musical melody using Multifractal (MF) analysis [6].

Fractal analysis lead to study of physical phenomena in different sciences as material science, fluid mechanics, chemistry, botany, including music's [7]. Fractal is a complicated pattern in mathematics built from simple repeated shape. The fractal dimension of a signal represents a powerful tool for detection [8]. For example, in analysis of electroencephalograms (EEG) and electrocardiograms (ECG), fractal has been used to identify and distinguish specific condition [9] [10]. Fractal also used in digital image processing [11] and digital signal processing [12] [13]. In musical signal analysis, Zlatintsi and Maragos [14] recognize musical instrument using MF analysis, while Das and Das [15] using fractal dimension analysis to recognize Indian musical instrument, Li, Tao, and Li [16] use fractal dimension for music feature extraction.



Higuchi fractal dimension is one of fractal algorithm that has been use for EEG of depression [17], digital images [18], heart murmur detection [19], also modeling trends in economy [20]. In this paper, we present classification of gamelan tones using Higuchi fractal dimension where as far as we know not done by other researchers.

Gamelan is one of the Indonesian traditional culture that existed since prehistoric times as proposed by the archaeologist Brandes. Javanese gamelan consists of a set of musical instruments that have a diatonic scales system called Pelog and Slendro that has a pentatonic scales system. The tones of Pelog are 1, 2, 3, 4, 5, 6, and 7 while Slendro are 1, 2, 3, 5, and 6. The gamelan instruments consist of 5 groups: Gongan (Gong Ageng, Gong Suwukan, Kempul, Kenong, Kethuk and Kempyang), Balungan (Demung, Saron, Peking, Slenthem), Bonang (Bonang Barung, Bonang Penerus), Panerusan (Gender Barung, Gender Panerus, Gambang, Siter, Suling) and Kendhang (Kendhang Ageng, Kendhang Ciblon, Kendhang Sabet, Kendhang Ketipung) [1].

Gamelan was made manually and tuning depend on the hearing of gamelan maker. Therefore, it is a need to classify the tones of the gamelan signals. A good classification requires accurate feature extraction. Recently, we have performed feature extraction of gamelan signals using Principal Component Analysis (PCA) which has better accuracy rather than using Fast Fourier Transform (FFT) or Discrete Wavelet Transform (DWT) [21].

## 2. Methods

### 2.1. Fractal dimension

Fractal derived from the word "fractus" in Latin means "broken". The fractal properties resemblance on all scales. Fractal geometry is the study of unorganized sets or functions that are not smooth. The fractal nature is a self-similarity at all scales. The term fractal dimension was proposed by Mandelbrot in 1975 after publishing his paper on the resemblance of self to the coastline of Britain. The fractal dimension is an important element because it can be defined and linked to real-world data, and can be measured in value by doing an experiment.

There are many methods to calculate fractal dimensions such as fractal dimensions of self-similarity, Richardson model's fractal dimension, box-counting method, hurt exponent, fractal dimension with mass size, fractal dimensions with the Higuchi method and fractal dimension by Katz method. In our research for classification of gamelan tones, we used Higuchi Dimensional Fractal (HDF). We choose HFD to calculate the fractal dimension because the HFD is very efficient in calculating the fractal dimension value of a curve and is suitable for time series data.

### 2.2. Higuchi fractal

The Higuchi method is one of the methods used to calculate the fractal dimension value of the waveform. The Higuchi method is a very efficient time series analysis method for determining the fractal dimension value of a curve [22]. Suppose a given time series  $Z(i)$  with  $i = 1, 2, \dots, N$ . The Higuchi method in time series to calculate the fractal dimension value are:

- a. From  $Z(i)$  we get new time series  $Z_p^n$

$$Z_p^n = \{Z(n), Z[n+p], \dots, Z[n + \text{int}(\frac{N-n}{p}) \cdot p]\} \quad (3.1)$$

where  $n$  and  $p$  are integer,  $p$  represents discrete time interval and  $n$  represent initial time with  $n = 1, 2, \dots, p$ .

- b. The length of new time series can define as:

$$L(n, p) = \frac{\left( \sum_{i=1}^{\text{int}(\frac{N-n}{p})} |Z[n+ip] - Z[n+(i-1)p]| \right) \frac{N-1}{\text{int}(\frac{N-n}{p})p}}{p} \quad (3.2)$$

where  $N$  is the length of original time series,  $\frac{N-1}{\text{int}(\frac{N-n}{p})p}$  represents norm factor and  $|Z[n+ip] -$

$Z[n+(i-1)p]| = r_i$ . So that  $L(n,p)$  is the sum of norm of the new segment length  $r_i$ . Every  $r_i$  indicates distance value  $n$  of two points, from  $n$  to  $z[n]$ , where  $n = 2, \dots, p$ .

- c. The length of time interval  $p$  can get from partition all subinterval  $L(n,p)$  with  $p$ .

For  $n = 1, 2, \dots, p$  it should be representing as:

$$L(p) = \frac{\sum_{n=1}^p L(n,p)}{p} \quad (3.3)$$

- d. The value  $L(p) \propto p^{HFD}$  where  $HFD$  is the value of *Higuchi fractal dimension* can be calculated by exponential law as below:

$$\begin{aligned} L(p) &= p^{-HFD} \\ L(p) &= \frac{1}{p^{HFD}} \\ HFD &= \frac{\log(L(p))}{\log \frac{1}{p}} \end{aligned} \quad (3.4)$$

### 2.3. K-Nearest neighbour

The K-Nearest Neighbor (K-NN) algorithm is a classification method by searching for groups of objects in the training data closest to or similar to the object in the test data. The K-NN algorithm is a method that uses the supervised learning algorithm. Supervised learning aims to discover new patterns in data by linking existing data patterns with new data.

The K-NN algorithm uses the classification of the environment as the predicted value of the new test sample. Distance used is Euclidean distance. Euclidean distance is the most common distance used in numerical data. Euclidean distance is defined as:

$$\mathcal{D}(x, y) = \sqrt{\sum_{k=1}^n (x_k - y_k)^2} \quad (3.5)$$

where  $\mathcal{D}$  is the distance between the points in the training data  $x$  and the test data  $y$  to be classified where  $x = x_1, x_2, \dots, x_i$  and  $y = y_1, y_2, \dots, y_i$  with  $i$  represents the attribute value and  $n$  is the attribute dimension.

### 2.4. Block diagram

Based on previous methods we developed experimental state for classification gamelan tones as depicted in Fig. 1.

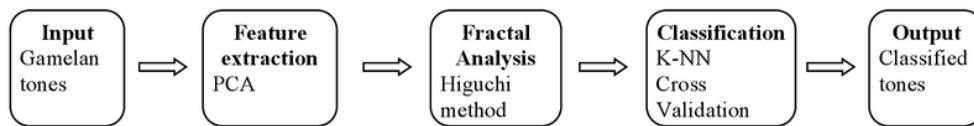


Fig 1. Block diagram of classification gamelan tones

First of all, we recorded gamelan instruments signal of every tone. After denoising and filtering, we extracted the feature of gamelan signals using PCA. Then we calculated the fractal dimension using Higuchi method. To classify the gamelan tones, we use K-NN and cross validation between data training and data testing.

## 3. Results and discussion

As an example, we take Demung Pelog signals to classify into 7 classes. Each tone is taken ten times. The value of HFD from every tone is depicted in Table 1.

11 **Table 1.** The value of Higuchi Fractal Dimension from Demung Pelog

| Signal no. | dp1      | dp2      | dp3      | dp4      | dp5      | dp6      | dp7      |
|------------|----------|----------|----------|----------|----------|----------|----------|
| 1          | 1.071473 | 1.09609  | 1.099952 | 1.106057 | 1.125633 | 1.145184 | 1.176286 |
| 2          | 1.071481 | 1.082939 | 1.099949 | 1.10606  | 1.12563  | 1.145228 | 1.179922 |
| 3          | 1.073591 | 1.078219 | 1.100657 | 1.106656 | 1.13559  | 1.143543 | 1.17552  |
| 4          | 1.072859 | 1.080688 | 1.105781 | 1.106201 | 1.128707 | 1.144647 | 1.175535 |
| 5          | 1.075167 | 1.087834 | 1.106277 | 1.107251 | 1.128934 | 1.142409 | 1.176764 |
| 6          | 1.072665 | 1.086163 | 1.122665 | 1.110273 | 1.130516 | 1.14255  | 1.174833 |
| 7          | 1.076933 | 1.083043 | 1.116675 | 1.10608  | 1.126904 | 1.1427   | 1.176265 |
| 8          | 1.077357 | 1.085506 | 1.097759 | 1.105818 | 1.12613  | 1.143042 | 1.175785 |
| 9          | 1.088845 | 1.086018 | 1.103681 | 1.107473 | 1.124597 | 1.142689 | 1.175083 |
| 10         | 1.080088 | 1.086133 | 1.085676 | 1.106116 | 1.127999 | 1.143449 | 1.177056 |

dp1 means signal of Demung Pelog tone 1, dp2 means signal of Demung Pelog tone 2, and so on. According to K-NN and cross validation, we get the accuracy of classification is 82.85%.

#### 4. Conclusion

This paper show that fractal analysis can be used for classifying the gamelan tones. Our experiment successful on classifying Demung Pelog tones into 7 classes as its notation. The result is a challenge to do the same on other instruments of gamelan also on Slendro scale.

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