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Terompong Basic Tone Synthesis with Frequency Modulation Method

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Abstract

Terompong is a type of gamelan in Bali Province. This gamelan is commonly used in traditional ceremonies in Bali, especially the Dewa Yadnya and Pitra Yadnya. The terompong are striking instruments, where the bat is made of wood. The terompong is also a two-octave musical instrument composed of 10-12 small metal gong blocks. The gong blocks are arranged parallel, which makes the gong difficult to carry and has to stay somewhere if someone want to play. Of course, with this situation people find it difficult to learn the terompong because they are quite large and heavy. This problem could be solved by replace the original terompong with synthetic terompong. The synthesis referred here the synthesis of sound. In performing sound synthesis, the method used is Frequency Modulation (FM). The result of the synthesis carried out where the difference between fundamental frequency of the original tone and the synthesis tone is almost close to zero. The sound produced almost follows the original sound, but it can't follow the sound of metal being hit with a wooden club.

Keywords: *Synthesis, Frequency Modulation*, *Terompong, Music, Basic Tone*

1. Introduction

Indonesia is a country with a variety of cultures. Each province has characteristics that distinguish one another, one of which is Bali. Bali is a province known for its nickname as the Island of the Gods. This nickname is inseparable from the inherent Balinese customs. Bali is not far from its dances and musical instruments, one of the famous musical instruments from this province is the gamelan. The Balinese gamelan is one type of traditional musical instruments in Indonesia, the Balinese call it "gambelan." This gamelan differs from the Javanese gamelan in terms of its thicker form, more forms, and faster rhythms. One of these Gamelan is the terompong. The terompong is a musical instrument with a two-octave range composed of 10-12 small metal gong blocks. The gong blocks are arranged parallel, which makes the gong difficult to carry and has to stay somewhere if you want to play it. Of course, with this situation people find it difficult to learn the terompong because they are quite large and heavy.

At recent days, technology plays a very big and important role in the arts and culture. Technology can be used to introduce and preserve culture. By utilizing existing technology, the sound of musical instruments can be made using the sound synthesis method. Sound synthesis is the process of producing sound. The process could be done by reuse existing sound by processing it, or by produce sound electronically or mechanically. This may use math, physics or even biology; and bringing together arts and sciences in a mix of musical skills and technical expertise [1]. In this paper, the sound synthesis of the gamelan terompong was carried out, where this synthesis is expected to help in studying terompong in the future without having to deal directly with the original terompong and still preserve Balinese culture.

There have been many studies conducted to synthesize the sound of traditional musical instruments including [2] and [3]. In research [2] the synthesis of rindik sounds was carried out using the modified frequency modulation (modFM) method, the synthesis stage was carried out by finding the basic frequency of rindik sounds using FFT (Fast Fourier Transform) and extracting envelopes from the original gamelan sound using the Hilbert transform method. The Hilbert transform is used to extract the envelope from the signal. The use of modFM focuses on increasing the complexity of the spectrum distribution pattern to increase the color of the sound that can be obtained. Based on this research, this study was proposed to find out whether the sound in the gamelan terompong can be synthesized properly. Unlike [2] and [3] paper, this paper uses Frequency Modulation. The development of FM technique into modFM focuses on increasing the complexity of the spectrum distribution pattern to increase the color of the sound that can be obtained [4]. Basis for selecting the frequency modulation in this study is whether this FM technique alone can succeed in building a traditional music sound. Using Fourier Transform, the components of the sound signal composition of terompong will be analyzed, then Frequency Modulation will be used to synthesize the sound of the gamelan terompong. Each basic note in terompong will be reconstructed, then the comparison will be analyzed between the results of the reconstruction (synthesis) and the original signal.

Based on the explanation above, this research was conducted to make sound synthesis of Terompong gamelan using the Fast Fourier Transform method as the extraction of the basic frequency of the gamelan, Hilbert transform as an envelope extraction from audio, and Frequency Modulation (FM) as a method for synthesizing the basic tone of a terompong.

2. Research Methods

2.1. Gamelan Terompong

Terompong is a type of gamelan in Bali Province. This gamelan is commonly used in traditional ceremonies in Bali, especially the Dewa Yadnya and Pitra Yadnya ceremonies. The gamelan terompong can be seen in Figure 1. The terompong are a musical instrument for striking, where the bat is made of wood. The terompong is also a musical instrument made up of 10-12 small gong blocks. This instrument has 10 small gong blocks and a pitch range of up to two octaves [5]. Terompong has a function to bring the melody and start a song or gending.

Figure 1 Gamelan Terompong
source: google.com

2.2. Data

The data used from this terompong instrument are all the basic tones so that all the basic frequency tones can be obtained with a total of 5 basic tones, where each note is recorded 4 times. Data recorded using a smartphone with a sample rate of 44100. Recording duration is 1 second for each recording with the waveform file format (.wav).

2.3. Method

a. Fundamental Frequency and Harmony Frequency

The signal consists of several frequencies, different amplitudes, and noise. In a signal there are two types of frequencies, fundamental frequency and harmony frequency. Fundamental frequency is the lowest frequency in a periodic wave. Meanwhile, harmonic frequencies are frequency components which are integer multiples of the fundamental frequency of a wave.

b. Fast Fourier Transform (FFT)

Fast Fourier Transform (FFT) is an algorithm of Discrete Fourier Transform (DFT) with fast calculations to perform Fourier transforms in the discrete domain [6]. FFT returns the two-sided spectrum values in real and imaginary form. The two-sided power spectrum becomes the frequency axis, while the amplitude of the FFT is related to the number of points in the time domain signal [7]. FFT is shown in equations (1) and (2).

$$\text{real } X[k] = \sum_{i=0}^{N-1} x[i] \cos\left(\frac{2\pi k_i}{N}\right) \quad (1)$$

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$$\text{imaginer X[k]} = \sum_{i=0}^{N-1} x[i] \sin(\frac{2\pi k_i}{N}) \quad (2)$$

with the amplitude in equation (3).

$$|X[k]| = \sqrt{(\text{RealX[k]})^2 + (\text{ImaginerX[k]})^2} \quad (3)$$

and the phase spectrum in radians in equation (4).

$$X[k] = \text{arctangent}\left(\frac{\text{ImaginerX[k]}}{\text{RealX[k]}}\right) \quad (4)$$

flowchart to find the fundamental frequency is shown in Figure 2.

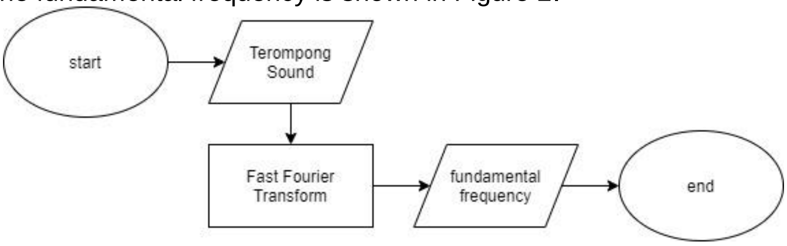

Figure 2 Fundamental Frequency Flowchart

Figure 2 is an illustration of the process of looking for frequency fundamentals, where the fundamental frequency is searched using FFT. This search process uses the python program which is sourced from https://gist.github.com/endolith/255291.

c. Hilbert's transformation

Hilbert transform is a technique used to find envelope, instantaneous phase, in a signal [8]. The Hilbert transform can be formulated in equation (5):

$$H[g(t)] = g(t) * \frac{1}{\pi t} \quad (5)$$

where:

H[g(t)] : Hilbert transform signal
g : original sound signal
t : time

flowchart to find the envelope of the original signal is shown in Figure 3.

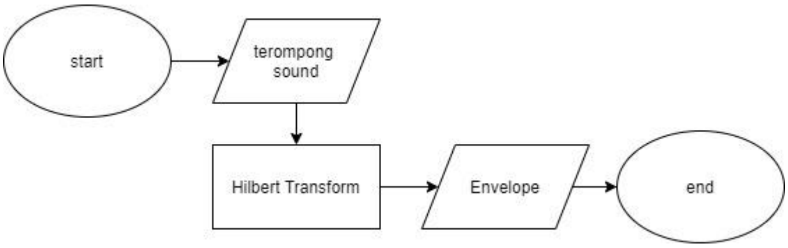

Figure 3 Hilbert's Transform flowchart

Figure 3 is the process of searching for the envelope of the original signal from the basic notes of the gamelan terompong. The record that will be used in searching for envelopes is one that is close to the average value of fundamental frequency. In looking for envelopes using the python program which makes use of the scipy library.

d. Frequency Modulation (FM)

Frequency Modulation is the modulation of the frequency of a carrier wave signal changing according to its message signal [9]. The frequency of the carrier wave (fc) increases as the message signal (input) amplitude increases. The carrier signal frequency will be maximum (fc max) when the message signal is at its peak. The operator deviates the maximum from its normal value. The carrier signal frequency decreases when the amplitude of the message (input) signal decreases. The carrier frequency will be minimum (fc min) when the message signal is at the lowest point [10]. Frequency Modulation is shown in equation (6).

$$f_m(t) = A\cos\left(\omega_c t + \frac{\Delta\omega}{\omega_m}\sin\omega_m t\right) \quad (6)$$

where, f_m (t) is the frequency wave that has been modulated, A is the amplitude of the carrier signal, ω_c is the corner frequency of the carrier signal, $\Delta\omega$ is the corner frequency of the carrier signal, and ω_m is the frequency of the message signal (modulator) [8].

2.4 Synthesis Process

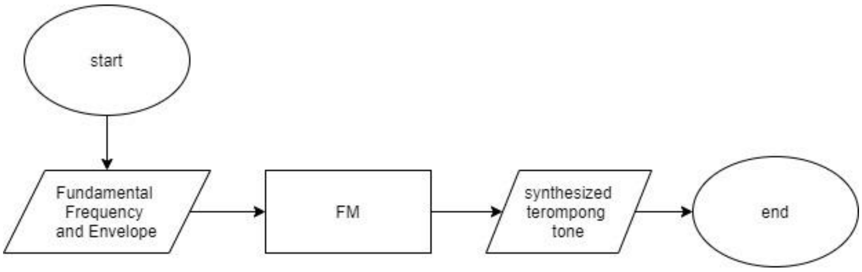

Figure 4 Synthesis Process

Figure 4 is a picture of the flow of the synthesis used in this paper, starting from the input parameters used that is the average fundamental frequency of each basic tone and the envelope of original basic tone sound. From the input, the synthesis is carried out using the FM method. The output of this synthesis is in the form of the basic tone sound of the synthesized gamelan terompong.

3. Results and discussion

3.1 Basic frequency of Gamelan Terompong

To get the fundamental frequency of the basic tone of the gamelan terompong a recording of the basic notes of the gamelan terompong is used as a dataset. The number of the dataset used is 20, which is divided into 5 notes, in each note has 4 records. The fundamental frequency obtained with FFT. The maximum, minimum and average values of each fundamental frequency then calculated. The result was fundamental frequency of each basic notes of the Terompong gamelan shown in Table 1.

Table 1. Fundamental Frequency of Each of the basic notes of the Terompong gamelan

Tone	Min (Hz)	Max (Hz)	Average
Ndang	188.38	233.53	222.22
Ndeng	312.09	589.86	498.72
Nding	265.37	492.91	435.99
Ndong	298.25	507.39	408.7
Ndung	387.06	702.67	623.79

3.2 Synthesis Process

The average value of fundamental frequency of the basic tone Terompong that will be used as input in synthesis process.
Apart from the basic input frequency, another input used in the synthesis process is the envelope. The Envelope signal is obtained using the Hilbert transform. The envelope resulting from Hilbert's transformation is used as message input when the synthesis of the basic gamelan tone. The data envelope used is generated from data that is close to the average frequency, the selected dataset is shown in Table 2.

Table 2. Dataset for Envelope Extraction

Nada	Ndang	Ndeng	Nding	Ndong	Ndung
Dataset	2	2	2	2	2

From table 2 is the second record data from the dataset is used to find the envelope. As mentioned above, these data have the closest fundamental frequency or nearly the average fundamental frequency of each tone.

3.3 Synthesis Results

Synthesis parameter in this paper was the average of base frequency of tones as carriers and envelopes of each tone as messages. The results of the synthesis of basic tones are shown in Table 3. The success rate of the synthesis of the basic notes of gamelan terompong is seen from the comparison between the original frequency or the basic tone average frequency with the basic frequency of the synthesized tone. In Table 3, the resulting frequency difference is close to zero. The tones of Ndang, Ndeng, Nding, and Ndong in synthesis tone were close to the original sound, but the Ndung tone sounds higher than the original sound. This is because it uses the frequency at the time of modulation, and does not pay attention to the existing amplitude. The distinctive clinking sound of metal on traditional instruments was not clear, and synthesis simply mimics the frequency and envelope of the original signal.

Table 3. Comparison of Synthesis and Original Tone Frequencies

Tone	Synthesis result in frequency	Original frequency	Differences
Ndang	222.24	222.22	0.02
Ndeng	498.7	498.72	0.02
Nding	436.05	435.99	0.06
Ndong	408.68	408.7	0.02
Ndung	623.72	623.79	0.07

4. Conclusion

The synthesis of the basic tone of the Terompong was successfully carried out. The frequency of the synthesis result and the record of basic note is almost the same. The difference between the original frequencies and the synthesized results is almost zero, but the distinctive sound of traditional metal instrument could not be shown. This synthesis result mimics the frequency and envelope of the original tone only.

In the future work, the sound synthesis research using the development of Frequency Modulation (FM) or the other methods was expected for better results, especially for imitate the distinctive clinking sound of metal on traditional instruments, so that synthetic sound of the basic tone of terompong will sound the same as the original ones.

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