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2019 INTERNATIONAL CONFERENCE OF ARTIFICIAL INTELLIGENCE AND INFORMATION TECHNOLOGY (ICAIIT 2019)

IEEE Conference Number #45307

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13 - 15 March 2019
Platinum Adisucipto Hotel & Conference Center
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International Conference of Artificial Intelligence and Information Technology 2019
Conference Schedule

Wednesday, 13 March 2019

Time	Activity		
08.00 - 09.00	Participants Registration & Materials Collection		
09.00 - 10.00	Welcome Speech & Opening Ceremony - General Chair of ICAIIT 2019 - Rector Kalbis Institute - Rector Universitas Atma Jaya Yogyakarta		
10.00 - 10.30	Coffee Break		
10.30 - 11.15	Keynote Speech 1 Professor Andrea Corradini (Copenhagen School of Design and Technology, Denmark) Speech Title: Multimodal Data Analysis		
11.15 - 12.00	Keynote Speech 2 HAIYONG WU, Ph. D (School of Information Engineering, Nanjing Xiaozhuang University) Speech Title: Deep Learning in Tractography		
12.00 - 13.00	Lunch		
13.00 - 15.00 (15 Minutes presentation per paper) ***Session 1:*** 1:13.00-13.15 2:13.15-13.30 3:13.30-13.45 4:13.45-14.00	**Titanium 1** 1.1570508359 2.1570526507 3.1570526480 4.1570526013 5.1570518440 6.1570519077 7.1570518796	**Titanium 2** 1. 1570512443 2. 1570512569 3. 1570514049 4. 1570507038 5. 1570512457 6. 1570526214 7. 1570513290	**Titanium 3** 1. 1570512696 2. 1570512578 3. 1570512583 4. 1570512614 5. 1570512722 6. 1570512735 7. 1570518672

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5:14.00-14.15 6:14.15-14.30 7:14.30-14.45				
15.00 - 15.30	Coffee Break			
15.30 - 17.00 (15 Minutes presentation per paper) ***Session 2:*** 1:15.30-15.45 2:15.45-16.00 3:16.00-16.15 4:16.15-16.30 5:16.30-16.45 6:16.45-17.00	**Titanium 1** 1.1570515432 2.1570526222 3.1570526304 4.1570526319 5.1570526544 6.1570526452	**Titanium 2** 1.1570513614 2.1570497900 3.1570497821 4.1570512658 5.1570523975 6.1570525893	**Titanium 3** 1.1570526455 2.1570526552 3.1570516699 4.1570513732 5.1570509093 6.1570526401	**Ballroom 1** 1. 1570521650 2. 1570526538 3. 1570526466 4. 1570526453 5. 1570524081 6. 1570513593
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09.45 - 10.30	Keynote Speech 4: Associate Professor Władysław Homenda (Warsaw University of Technology, Poland) Speech Title: Cognitive Maps for Time Series Modeling			
10.30 - 11.30 (15 Minutes presentation per paper) ***Session 3:*** 1:10.30-10.45 2:10.45-11.00 3:11.00-11.15 4:11.15-11.30	**Titanium 1** 1.1570526412 2.1570526525 3.1570516332 4.1570526533	**Titanium 2** 1. 1570526555 2. 1570526750 3. 1570508178 4. 1570526557	**Ballroom 1** 1. 1570526547 2. 1570526500 3. 1570511011 4. 1570522671	**Ballroom 2** 1. 1570526541 2. 1570512562 3. 1570513741 4. 1570513710
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Friday, 15 March 2019

Time	Activity
07.00 - 20.00	Excursion (for Full Package only)

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1	13.30-13.45	1570526480	Predicting Candidates For Fit And Proper Test Using K-Nearest Neighbor
1	13.45-14.00	1570526013	Adapted Flower Pollination Algorithm for Lecturer-Class Assignment
1	14.00-14.15	1570518440	Predictive Analytics for Predicting Customer Behavior
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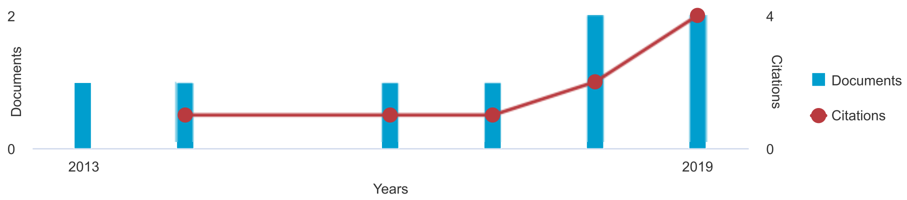

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***Abstract*— Generally, a sampling frequency of chord recognition systems follows the Shannon sampling theorem. This paper investigates the influence of sampling frequency that does not follow the Shannon sampling theorem in a chord recognition system. The chord recognition system uses a transform domain approach that makes use a DST (Discrete Sine Transform). In addition, the chord recognition system uses segment averaging for feature extraction. An acoustic-electric guitar is used in this work. Based on the experiments, a decrease in the sampling frequency from 2500 Hz down to 156 Hz has almost no influence in the recognition rate. As a first note, we only consider the recognition rate above 95%. As a second note, we use at least frame blocking length of 128 points and feature extraction length of 16 points. Therefore, if that kind of recognition rate could be accepted, the sampling frequency as low as 156 Hz could still be used for guitar chord recognition.**

Keywords— sampling frequency, chord recognition, segment averaging

I. INTRODUCTION

In the field of signal processing there is a process named the sampling process. This process aims to convert analog signals to digital signals. The sampling process requires a sampler. A main parameter in the sampler is the sampling frequency. Generally, the magnitude of sampling frequency on the sampler follows the Shannon sampling theorem. This theorem is followed in order that in the reverse process, namely the process of converting digital signals to analog signals, these analog signals can be perfectly recovered [1].

In the field of pattern recognition relating to chord recognition, the Shannon sampling theorem is generally followed. Previous researches relating to chord recognition were generally based on PCP (Pitch Class Profile) and its derivatives [2-7]. These researches were based on transform domain approaches that made use the fundamental frequencies of chords. Basically, if the sampling frequencies of these researches do not follow the Shannon sampling theorem, the fundamental frequencies of chords can not be perfectly obtained.

As described above, there were no previous researches, relating to chord recognition used sampling frequencies that did not follow the Shannon sampling theorem. Therefore, a research of a chord recognition that makes use of sampling frequencies that do not follow the Shannon sampling theorem, is still open. As a note, if we use sampling frequencies that do not follow the Shannon sampling theorem, we will have smaller data for processing.

This paper will investigate the influence of sampling frequencies that do not follow the Shannon sampling theorem, on a chord recognition system. The chord recognition system in this work uses a transform domain approach. A DST is used in this transform domain approach. In this case, this transform domain approach does not use fundamental frequencies.

II. RESEARCH METHOD

A. System Development

A developed chord recognition is shown in Fig. 1. The input is a recording of an isolated chord signal in wav format. The output is a character that indicates a recognized chord. The input of the chord recognition system and also the function of each block of the chord recognition system are explained in details below.

The input

The input of the chord recognition system is a recording of chord signals in an isolated wav format. The chord signals were acquired from an acoustic-electric guitar Yamaha CPX 500-II as shown in Fig. 2.

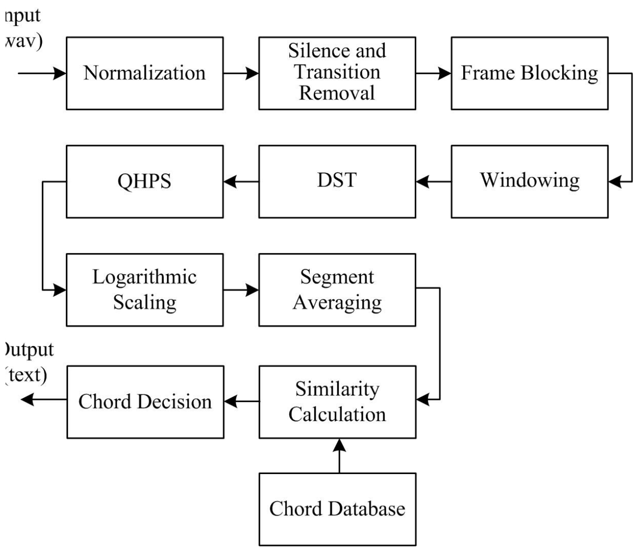

Fig.1. Block diagram of the developed chord recognition system.

The chord signals were recorded using various sampling frequencies: 2500Hz, 1250 Hz, 625 Hz, 312 Hz, 156 Hz, and 78 Hz. The highest sampling frequency of

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Fig. 2. The acoustic-electric guitar used in this work.

2500Hz was chosen because it had followed the Shannon sampling theorem [1]:

$$f_s \geq 2 f_{\max} \quad (1)$$

where f_{max} is the highest fundamental frequency of tone G4 (392 Hz) from the G chord, and f_s is the sampling frequency. Based on the evaluation, the recording duration of 2 seconds was sufficient to obtain the sufficient steady state region for the frame blocking process. As a note, we used major chords C, D, E, F, G, A, and B in this work. Furthermore, in this paper, while the chords C, D, E, F, G, A, and B are mentioned, they are indicated as major chords.

Normalization

Normalization is the process of making the maximum absolute value of the input signal data to the value 1. Normalization is needed because the input signal data has a variation on its maximum absolute value. Normalization is done using the following equation.

$$\mathbf{x}_{\text{out}} = \mathbf{x}_{\text{in}} / \max(|\mathbf{x}_{\text{in}}|) \quad (2)$$

where $\mathbf{x}_{in}$ and $\mathbf{x}_{out}$ are the input and the output of signal data vectors of normalization process respectively.

Silence and transition removal

Silence and transition removal is a process for removing silence and transition areas from the signal data. Silence and transition areas are located on the left side of the signal data. Based on observations, the amplitude threshold |0.5| was needed to remove the silence area. Starting from the leftmost area of the signal data, if the signal's amplitude is less than |0.5| then the signal data is removed. After the removal of the silence area, the removal of the transition area is carried out. Based on observations, the removal of 200 milliseconds of signal data from the left side area is needed, in order to remove the transition area.

Frame blocking

Frame blocking is a process for obtaining a short signal data from a long signal data [10]. This short signal data will reduce the amount of data that will be processed by the chord recognition system. The advantage of this smaller amount of data is the reduced computing time. In this work, the frame blocking length is 2^n, where n is a positive integer.

Windowing

Windowing is a process for lowering the appearance of discontinuities at the edges of signal data [10]. The appearance of this discontinuity is caused by the cutting of signal data in the frame blocking above. This discontinuity will generate harmonic signals in the transformed signal data. This work used the Hamming window [11] for the purposes of windowing. This kind of windows is a window that is widely used in digital signal processing [12]. In this work, the window length is equal to the frame blocking length.

DST

DST is a process for transforming signal data from the time domain to the DST domain. DST is a type of transformation that is derived from DFT (Discrete Fourier Transform). For the sequence of signal data $x(n)$ with a length of N points, the DST of the sequence is mathematically formulated as follows.

$$X(k) = \sqrt{\frac{2}{n+1}} \sum_{n=0}^{N-1} x(n) \sin\left[\frac{\pi(n+1)(k+1)}{N+1}\right] \quad (3)$$

where $0 \leq n \leq N-1$. In this work, the value of N used in the DST calculation is equal to the frame blocking length. In addition, in this work the calculation of the absolute value of DST is used, because there is a subsequent process, namely logarithmic scaling, which does not allow calculations with negative values.

QHPS (Quasi Harmonic Product Spectrum)

QHPS is a process for eliminating unwanted harmonic signals. This paper proposes this QHPS that derived from original HPS (Harmonic Product Spectrum) [13]. Based on the observations, QHPS could make the difference between a chord with the other chords became clearer. This QHPS algorithm is shown as follows.

QHPS Algorithm

1. Consider a sequence $X(k)=\{X(0), X(1), \dots, X(N\text{-}1)\}$ with $N=2^p$ and $p \geq 0$.
2. Do sequence downsampling for X(k) in order to get

$$X_D(k)=\{X(0), X(2), \dots, X(N\text{-}2)\}$$

3. Do sequence cutting for $X(k)$ in order to get

$$X_C(k) = \{X(0), X(2), \dots, X((N/2)\text{-}1)\}$$

4. Do element multiplication between $X_D(k)$ and $X_C(k)$ in order to get the QHPS result

$$Y(k) = X_D(k) \,.\, X_C(k) \quad (4)$$

In this work, the value of N used in the QHPS process is equal to the frame blocking length.

Logarithmic scaling

Logarithmic scaling is the process for increasing the appearance of significant local peaks. This logarithmic scaling is needed because, based on previous researches using segment averaging feature extraction [8,9], there was an indication that segment averaging feature extraction showed better results for signal data that have many significant local peaks. Mathematically, this logarithmic scaling is shown as follows.

$$\mathbf{Y}_{out} = \log(\alpha \mathbf{Y}_{in} + 1) \quad (5)$$

where $\mathbf{Y}_{in}$ and $\mathbf{Y}_{out}$ are the input and the output of signal data vectors of logarithmic scaling process respectively. The value of α is called a logarithmic scale factor. There is an addition of '1' in the above formula. This addition is intended to avoid infinite logarithmic results, when there is a zero value in the $\mathbf{Y}_{in}$ vector element.

Segment averaging

Segment averaging is the process of getting a shorter signal data sequence, from a longer signal data sequence. Basically, this shorter signal data sequence still shows the basic form of a longer signal data sequence. This work used the segment averaging algorithm inspired by Setiawan [14]. The segment averaging algorithm is shown as follows.

Segment Averaging Algorithm

1. Consider the sequence $Y(k) = \{Y(0), Y(1), \dots, Y(N\text{-}1)\}$ where $N = 2^p$ and $p \geq 0$.
2. Set the segment length L, where $L = 2^q$ for $0 \leq q \leq p$.
3. Divide the sequence $Y(k)$ by using the segment length L. Thus it will be will be resulted a number of M segments as follows

$$M = \frac{N}{L} \quad (6)$$

and also the sequence $G(u)=\{G(1), G(2), \dots, G(L)\}$ in each segment.

4. Calculate the average value for each segment $S(v)$ in order to get the result of the segment averaging

$$S(v) = \frac{1}{L}\sum_{u=1}^{L} G_v(u), \quad 1 \leq v \leq M \quad (7)$$

The result of the segment averaging process $S(v)= \{S(1), S(2), \dots, S(M)\}$ is called as the feature extraction from the input signal. In this work, the value of N in the segment averaging process is equal to the frame blocking length.

Similarity calculation

Similarity calculation is the process of calculating a number of similarity values, between feature extraction from the input signal with a number of reference feature extractions stored in a chord database. This similarity calculation indicates that the guitar chord recognition system in this work uses the template matching method [15,16]. This work uses cosine similarity for the similarity calculation. Cosine similarity is a calculation of similarity that has been popularly used [17].

Chord decision

Chord decision is a process of finding a chord that corresponds to the input signal. The first step of the chord decision is to find a maximum value from a number of similarity values. This number of similarity values are the result of the previous similarity calculation process. The second step of the chord decision is to find an output chord, which corresponds to the one of the feature extraction chord in the chord database, which has the highest similarity value.

B. Chord Database

A chord database is shown in Fig. 1. Based on Fig. 1, the chord feature extraction is shown in Fig. 3. The input from the chord feature extraction is a recording of chord signal in the isolated wav format, while the output is a chord feature extraction.

In this work, a number of 10 samples of chord signals were taken for each chord C, D, E, F, G, A, and B. In this case, it was assumed that all of the signal variations of each chord could obtained by taking 10 samples for each chord. A total of 10 samples for each chord will give 10 feature extractions for each chord. Furthermore, the feature extraction results for each of these chords are averaged to obtain a reference feature extraction for each chord, as follows.

$$\mathbf{Z}_T = \frac{1}{10}\sum_{i=1}^{10} \mathbf{S}_i \quad (8)$$

where the vector $\{\mathbf{S}_i \mid 1 \leq i \leq 10\}$ are 10 feature extraction results for each chord, and the vectors $\{\mathbf{Z}_T \mid T = \text{C, D, E, F, G, A, and B}\}$ are the seven reference feature extraction stored in a chord database. As a note, a single reference feature extraction is generated from a single sampling frequency value, a single frame blocking length value, and a single feature extraction length value.

C. Test Chords

Test chords are the chords used to test the recognition performance of the chord recognition system. The test chords consist of 70 chords. This test chords came from seven chords C, D, E, F, G, A, and B, where each chord recorded repeatedly as many as 10 times. In this work, the test chords were used to test performance on each sampling frequency, each frame blocking length, and each feature extraction length.

D. Recognition Rate

Recognition rate is a performance indicator of the chord recognition system. In this work, the recognition rate is a comparison between the number of chords that are correctly recognized with the number of chords tested. The recognition rate is formulated mathematically as follows.

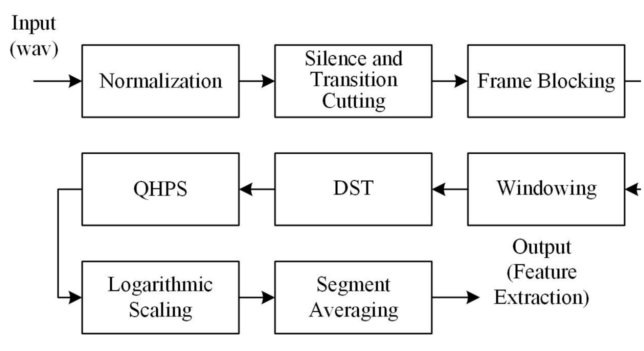

Fig.3. Block diagram of the chord feature extraction.

$$\text{Recognition rate} = \frac{\text{Number of correct chords}}{\text{Number of test chords}} \times 100\% \quad (9)$$

III. Results and Discussion

A. Test Results

We used the chord recognition system shown in Fig. 1, to test the influence of sampling frequency on the guitar chord recognition. The test results are shown in Table I. As a note, the test results in Table I were obtained by using the value of 100 on the logarithmic scale factor.

Table I indicates that from a sampling frequency of 2500 Hz down to 156 Hz (by using frame blocking length of 128 and 256 points and also feature extraction length of 16, 32 and 64 points), there are almost no influence in the recognition rates, if we only consider the recognition rates above 95%. By considering the recognition rate above 95%, the lowest sampling frequency and the shortest feature extraction length obtained are 156 Hz and 16 points, respectively.

TABLE I. Results of chord recognition test. Results shown: Recognition rate (%)

Frame blocking length (points)	Feature extraction length (points)						
	1	2	4	8	16	32	64
(a) f_s = 2500 Hz							
16	14.29	27.14	18.57	–	–	–	–
32	14.29	20.00	28.57	45.71	–	–	–
64	14.29	38.57	50.00	70.00	87.14	–	–
128	14.29	25.71	47.14	78.57	**95.71**	97.14	–
256	14.29	37.14	70.00	85.71	**95.71**	98.57	100
(b) f_s = 1250 Hz							
16	14.29	22.86	28.57	–	–	–	–
32	14.29	24.29	27.14	47.14	–	–	–
64	14.29	17.14	40.00	65.71	91.42	–	–
128	14.29	18.57	40.00	72.86	**95.71**	97.14	–
256	14.29	22.86	51.42	74.29	**97.14**	98.57	98.57
(c) f_s = 625 Hz							
16	14.29	25.71	30.00	–	–	–	–
32	14.29	27.14	47.14	67.14	–	–	–
64	14.29	32.86	45.71	62.86	77.14	–	–
128	14.29	32.86	55.71	75.71	**97.14**	98.57	–
256	14.29	24.89	58.57	82.86	**97.14**	97.14	98.57
(d) f_s = 312 Hz							
16	14.29	27.14	48.57	–	–	–	–
32	14.29	34.29	58.57	65.71	–	–	–
64	14.29	35.71	62.86	75.71	82.86	–	–
128	14.29	35.71	64.29	87.14	**97.14**	97.14	–
256	14.29	34.29	65.71	84.29	**95.71**	98.57	98.57
(e) f_s = 156 Hz							
16	14.29	27.14	48.57	–	–	–	–
32	14.29	34.29	70.00	71.42	–	–	–
64	14.29	44.29	64.29	77.14	91.43	–	–
128	14.29	41.43	72.86	90.00	**95.71**	98.57	–
256	14.29	52.86	82.86	95.71	**95.71**	98.57	98.57
(f) f_s = 78 Hz							
16	14.29	34.29	38.57	–	–	–	–
32	14.29	41.43	60.00	70.00	–	–	–
64	14.29	40.00	68.57	75.71	90.00	–	–
128	14.29	32.86	65.71	72.86	87.14	92.86	–

From the point of view of sampling frequency, the highest frequency component is 392 Hz (tone G4) that come from chord G. Therefore, based on this highest frequency component, equation (1), and also Table I, the sampling frequency of 2500 Hz down to 1250 Hz, follow the Shannon sampling theorem. Starting from a sampling frequency of 625 Hz and below, the sampling frequencies do not follow the Shannon sampling theorem.

From the point of view of signal reconstruction, in general, when the sampling frequency decreases, the aliasing area will increase. This aliasing area is located in the high frequency region. The effect that arises from the increase in the aliasing area is a lowpass filtering with a decreasing cutoff frequency. For the same reason, from the point of view of signal sampling, if the sampling frequency decreases, the low pass filtering effect with a decrease in the cutoff frequency will also appear. The result is that there will be fewer numbers of significant frequency components. Therefore, if the number of significant frequency components (significant local peaks in the DST domain) from the signal becomes fewer, the number of data used to distinguish one chord with the other chords becomes fewer. This event will reduce the recognition rate.

From the point of view of data size, based on Table I, a decrease in the sampling frequency of 93.76% (from 2500 Hz down to 156 Hz) will also reduce data size by 93.76%. However, a decrease in this data size has almost no influence in the recognition rate, if we use at least frame blocking length of 128 points and feature extraction length of 16 points. This case indicates that up to as slow as 156 Hz for the sampling frequency, if we use at least frame blocking length of 128 points and feature extraction length of 16 points, the chord recognition system is not sensitive to sampling frequencies that do not follow the Shannon sampling theorem.

Logarithmic scaling

The logarithmic scaling process as shown in Fig. 1, uses the logarithmic scale factor shown in equation (5). As shown in Table II, the logarithmic scale factor that is too small or too large will reduce the recognition rate. The decrease in the recognition rate is due to the increasing level of feature extraction similarity. Basically, the increasing level of feature extraction similarity will result in more difficulty in distinguishing between one feature extraction pattern and the other feature extraction patterns. As a result of this increasing level of feature extraction similarity is a decrease in the recognition rate. Based on Table II, the smallest optimal value for the logarithmic scale factor is 100.

TABLE II. The effect of logarithmic scale factor on the recognition rate, on sampling frequency of 156 Hz, and feature extraction length of 16 points

Logarithmic scale factor	1	10	100	1000	10000
Recognition rate (%)	91.43	94.29	95.71	95.71	94.29

IV. Conclusion

This work aimed to investigate the effect of sampling frequencies that did not follow the Shannon sampling theorem on the guitar chord recognition system. In this case, the chord recognition system used a transform domain approach by making use of a DST. In addition, the chord recognition system used segment averaging for feature extraction.

Based on our experiments, a decrease in the sampling frequency of 2500 Hz down to 156 Hz has almost no effect in the recognition rate. In this case, as a first note, we only consider the recognition rate above 95%. As a second note, we use at least frame blocking length of 128 points and feature extraction length of 16 points.

For further research, the investigation of the sampling frequency that does not meet the Shannon sampling theorem can be applied to other chord recognition systems. In this case, the chord recognition systems use other than a segment averaging for feature extraction.

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