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SPECTRAL FEATURES AND MUSIC SCALE OF MYANMAR BAMBOO XYLOPHONE

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Abstract

Myanmar Bamboo Xylophone (Pattalar) is one of the famous Myanmar fixed-pitch musical instruments, which produce a pleasant sound. Pattalars have their own unique sound with unique parameters different from other musical instruments. The purpose of this paper is to analyzed spectral features of the sound of Pattlar with traditional tuning. The parameters of spectral features such as pitch, harmonics are extracted by short time Fourier transform (STFT). The accurate spacing of harmonic contents and spectral envelope are computed by cepstrum analysis. Then, the frequency contents of signal changes over time are visualized by spectrogram method. The tuning of Pattalar is studied by three different Pattalars with the music scale computed in a logarithmic unit called Cents. The resulting measurements are compared with the pervious measurements data reported by Professor J.West, Professor Dr Maung Maung Kha.

Keywords: STFT, Spectrogram, cepstrum, Pattalar, Myanmar music scale, Cents

Introduction

Myanmar Bamboo Xylophone (Pattalar) is one of the famous musical instruments have been existence during Innwa period (14^{th}-15^{th} century A.D). This is a fixed-pitch instrument including in idiophone class, which produce sounds through the vibration of their entire body. A Pattalar consists of three octaves, including 24 slates and they are made by 'Waboe' bamboo. Under the 24 slats, there is a wooden resonator to produce pleasant sounds. Pattalars are tuned in diatonic scale contains seven notes for an octave. The tuning of Bamboo Pattalar are studied from three different Pattalars and compared with Myanmar musical scale and traditional tuning of Pattalar reported by the previous researchers Robert Muriel. C Williamson (1956) and Dr Maung Maung Kha (1962). The music intervals between two successive notes are calculated in a logarithmic unit called Cents. The first one is a bamboo Pattalar made by Professor Dr Maung Maung Kha since 1962 and others two from Arts and Culture Club of University of Yangon [Muriel C Williamson, (2000)].

Pattalar has their own unique sound with unique parameters called timbre. The two general classes for identified timbre are temporal features and spectral features. In this paper, only spectral features are studied. The spectral parameters such as pitch, harmonics and their relative amplitudes are obtained by short time Fourier transform (STFT). The frequencies contents such as pitch, harmonics with their relative amplitudes varying over time are visualized by Spectrogram. The spectrum of the sound is very flat and it is confused to understand by containing a large numbers of harmonics. However, cepstrum has the ability to detect the harmonic pattern and an accurate indication of the harmonic spacing. Then, the spectral envelope is computed by cepstrum analysis, it is the important parameter for sound analysis, synthesis and classification timbre of musical instrument [R. B. Randall, (1987)].

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Musical Scale of Bamboo Pattalar

Pattlars are tuned in a diatonic musical scale containing seven notes for an octave, athan-zin-hkun-napa` or 'set of seven sounds'. They are tuning in descending scale of diatonic (C B A G F E D), Tapauk, Hkun-napauk, Chauk- pauk, Nga-pauk, Lei`-pauk, Thone-pauk, Hna-pauk. However they are not really Western diatonic scale, the common note-set of Myanmar traditional notation can be described as a mixture of four Western tones and three neutral tones (tones lowered about a quarter tone), C D E* F G A* B*, asterisks indicate the neutral tones (Muriel Williamson). The musical interval can be measured in units called cents, mathematically expressed as

$$\text{cents} = 1200 \log_2\left(\frac{f_1}{f_2}\right) = 3986 \times \log_{10}\left(\frac{f_1}{f_2}\right) \qquad (1)$$

From the above equation, f_1 and f_2 are the frequencies of the successive lower and upper notes. Table (1) shows the comparisons of music scale intervals between Western and Myanmar reported by the previous researchers (Dr Maung Maung Kha, 1963; U Khin Zaw, 1940; Muriel C. Williamson, 1956). Column (1) is C-major scale interval of Western music scale, Column (2) is nayin-lon scale of Myanmar traditional harp, Column (3) is the measurements of brass bar Pattalar reported by Professor J.West and Column (4) is the measurement of bamboo Pattalar reported by Professor Dr Maung Maung Kha [Muriel C Williamson, (2000)].

Table 1 The Comparison of Western music scale and Myanmar Music scale from Harp and Pattalar

Notes	Western (1)	Harp (2)	West (3)	Dr MMK (4)
C	1200	1200	1200	1213
B	1100	1050	1035	1071
A	900	900 (850)	889	890
G	700	700	717	700
F	500	500	534	511
E	400	350 (400)	373	380
D	200	200	199	186
C	0	0	0	0

Audio Recording and Spectrum Analysis

There are many background of study to analyze the music features and transform the sound of musical instrument to numerical data. The first step is recording process to achieve data as an audio file. In this work, individual notes of three different Pattalars are recorded by audio software Audicity with 44100Hz sampling frequency, 32-bit float sample format and .wav file. Figure (1) shows the recording of Pattalars from Arts and Culture Club of University of Yangon. The important parameters of spectral features such as pitch, harmonics and their relative amplitude of the sound signal are obtained by short time Fourier transform (STFT). Then, the spectrogram described time-frequency representation obtained by the magnitude of (STFT) and the intensity or amplitude of the harmonics spectrum are computed on a log scale (dB). The parameters of spectrogram such as window length, window type, hop-size, and segment length are choosing for finer time and frequency resolution. The cepstrum is logarithmic conversion of the original spectrum and has the ability to detect the periodic structures in a logarithmic spectrum, such as families of harmonics or sidebands with uniform spacing [R. B. Randall, (1987)].

The spectral envelope obtained by cepstrum windowing is defined as

$$Y_m = DFT[\underbrace{\omega.DFT^{-1}log(|X_m|)}_{\text{Real cepstrum}}]$$

where ω is a lowpass-window in the cepstrum domain. The log-magnitude spectrum of X_m is thus lowpass filtered (the real cepstrum of **x** is ''liftered'') to obtain a smooth spectral envelope. The unit of the cepstrum is quefrency, getting by the inversing of frequency, similarly cepstrum is the steaming from an inversion of spectrum, rahmonic from harmonic, lifter from filter and gamnitude from magnitude [Julius O. Smith III, (2011)]. All the processing is done by Matlab programming.

(a) (b) (c)

Figure (1) (a) Dr Maung Maung Kha's Pattalar (b) The first Pattalar from University of Yangon (c) The second Pattalar from University of Yangon

Result and Discussion

The fundamental frequencies or pitch of each musical notes for three different Pattlars are shown in table (2). By using equation (1) the music interval between two successive notes computed in cents is shown in table (3). The comparison of the music scale between Western diatonic, Myanmar traditional tuning and the resulting of three different Pattalars is shown in figure (2). However, figure (2) is only for middle octaves, in this figure the tuning of three Pattalars is not the same; they are varied about ±25 cents, less than a quarter tone. This is in the range between musical significant pitch changes (±25 cents) summarized by Muriel C. Willianson. But it is not for the lower and upper octave. From the computation data of table (3), some of notes especially in the lower octave varied closed to 100 cents, a semitone.

Figure (3) is the spectrogram of 1-Pauk 1 note with the segment length of 4096 samples Hanning window and 50% overlap ratio. In this figure, the fundamental frequency, harmonics with the relative intensity varying over time are represented by colored. The brighter color represents the higher intensity and the darker to the lower. The difference between spectrum and cepstrum is manily lie in the low quefrency parts of the cepstrum, which is dominated by formant characteristics. Figure (4) is the amplitude spectrum and amplitude cepstrum of 1-Pauk 1 note. Cepstrum described harmonic pattern and an accurate indication of the harmonic spacing, 72Hz corresponds to 13.9161ms, 48Hz corresponds to 20.8118 ms, 36Hz corresponds to 27.8277 ms and 28Hz corresponds to 34.4853 ms respectively. Figure (5) is the spectral envelope computed from real cepstrum. Firstly cepstrum coefficients are transformed back to the frequency domain. Then, the local maximum points are extracted from frequency spectrum and finally, spectral envelope is obtained by interpolation method.

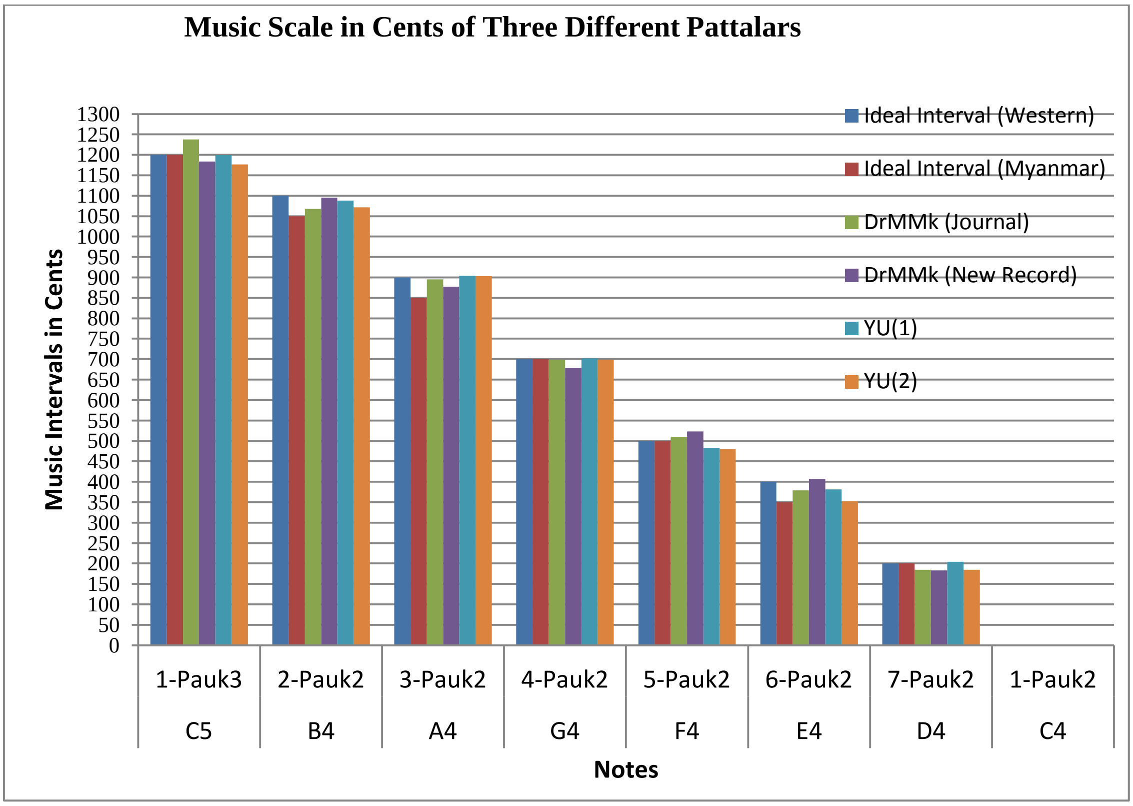

Figure 2 Music Scale in Cents of Three Different Pattalars

Table 2 Frequencies Tuning of Three Different Pattlars

Notes Western	Notes Myanmar	Dr MMK (Journal)	Dr MMK (New)	Yu (1)	Yu (2)
E6	6-Pauk4	1364	1354	1314	1330
D6	7-Pauk4	1222	1195	1180	1172
C6	1-Pauk4	1096	1053	1043	1044
B5	2-Pauk3	995	988	980	989
A5	3-Pauk3	884	872	878	877
G5	4-Pauk3	800	774	782	779
F5	5-Pauk	722	705	702	699
E5	6-Pauk3	661	656	658	655
D5	7-Pauk3	594	579	584	588
C5	1-Pauk3	543	516	527	524
B4	2-Pauk2	492	490	494	493
A4	3-Pauk2	445	432	444	447
G4	4-Pauk2	397	385	395	397
F4	5-Pauk2	356	352	348	350
E4	6-Pauk2	330	329	328	325
D4	7-Pauk2	295	289	296	295
C4	1-Pauk2	265	260	263	265
B3	2-Pauk1	243	246	242	248
A3	3-Pauk1	217	217	224	228
G3	4-Pauk1	194	191	194	195
F3	5-Pauk1	173	173	175	179
E3	6-Pauk1	160	164	163	170
D3	7-Pauk1	143	147	146	152
C3	1-Pauk1	128	121	129	138

Table 3 Music Scale in Cents of Three Different Pattlatrs

Notes Western	Notes Myanmar	Ideal Interval western (W)	Ideal Interval Myanmar (T)	Frequency-1 (Hz) Dr MMK (Journal)	Frequency-2 (Hz) Dr MMK (New)	Frequency (Hz) Yu (1)	Frequency (Hz) Yu (2)
E6	6-Pauk4	2800	2750	2828	2850	2772	2785
D6	7-Pauk4	2600	2600	2638	2634	2586	2567
C6	1-Pauk4	2400	2400	2450	2416	2373	2367
B5	2-Pauk3	2300	2250	2283	2306	2266	2274
A5	3-Pauk3	2100	2050	2079	2090	2076	2066
G5	4-Pauk3	1900	1900	1907	1884	1876	1861
F5	5-Pauk3	1700	1700	1730	1723	1694	1674
E5	6-Pauk3	1600	1550	1578	1599	1582	1562
D5	7-Pauk3	1400	1400	1393	1383	1376	1376
C5	1-Pauk3	1200	1200	1238	1184	1199	1177
B4	2-Pauk2	1100	1050	1068	1095	1088	1072
A4	3-Pauk2	900	850	895	877	904	903
G4	4-Pauk2	700	700	698	678	702	698
F4	5-Pauk2	500	500	510	523	483	480
E4	6-Pauk2	400	350	379	407	381	352
D4	7-Pauk2	200	200	185	183	204	185
C4	1-Pauk2	0	0	0	0	0	0
B3	2-Pauk1	-100	-150	-150	-95	-144	-114
A3	3-Pauk1	-300	-350	-345	-312	-277	-259
G3	4-Pauk1	-500	-500	-538	-532	-525	-529
F3	5-Pauk1	-700	-700	-736	-703	-703	-677
E3	6-Pauk1	-800	-850	-871	-795	-825	-766
D3	7-Pauk1	-1000	-1000	-1065	-984	-1015	-959
C3	1-Pauk1	-1200	-1200	-1256	-1320	-1229	-1126

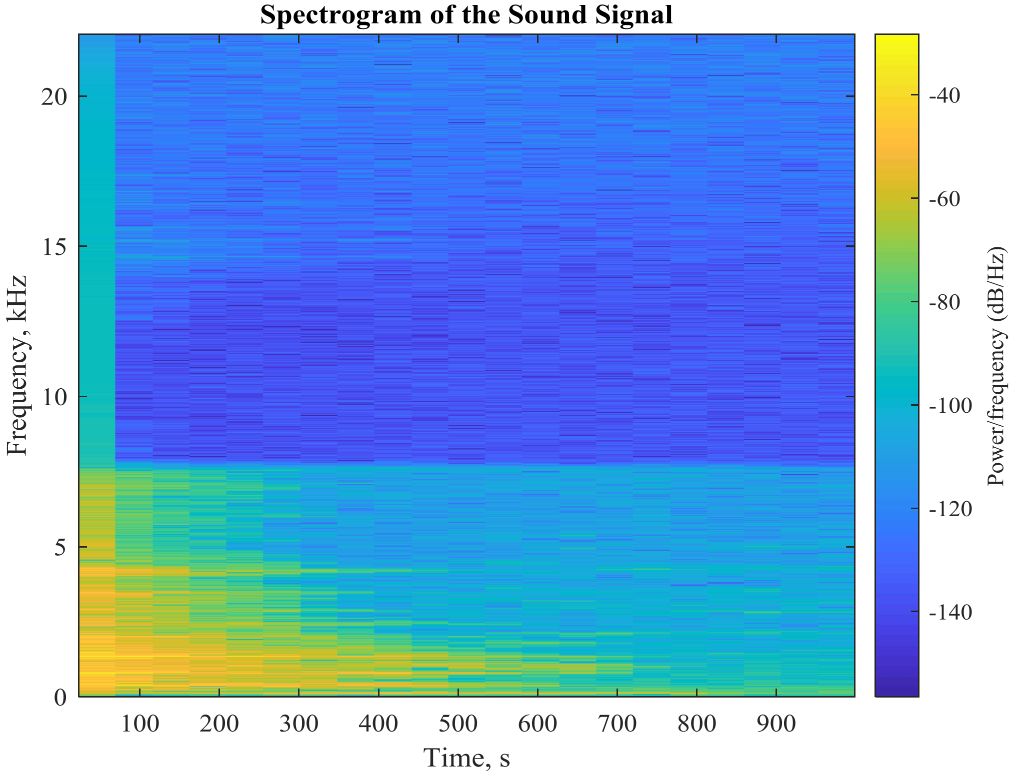

Figure 3 Spectrogram of the 1-Pauk1 note

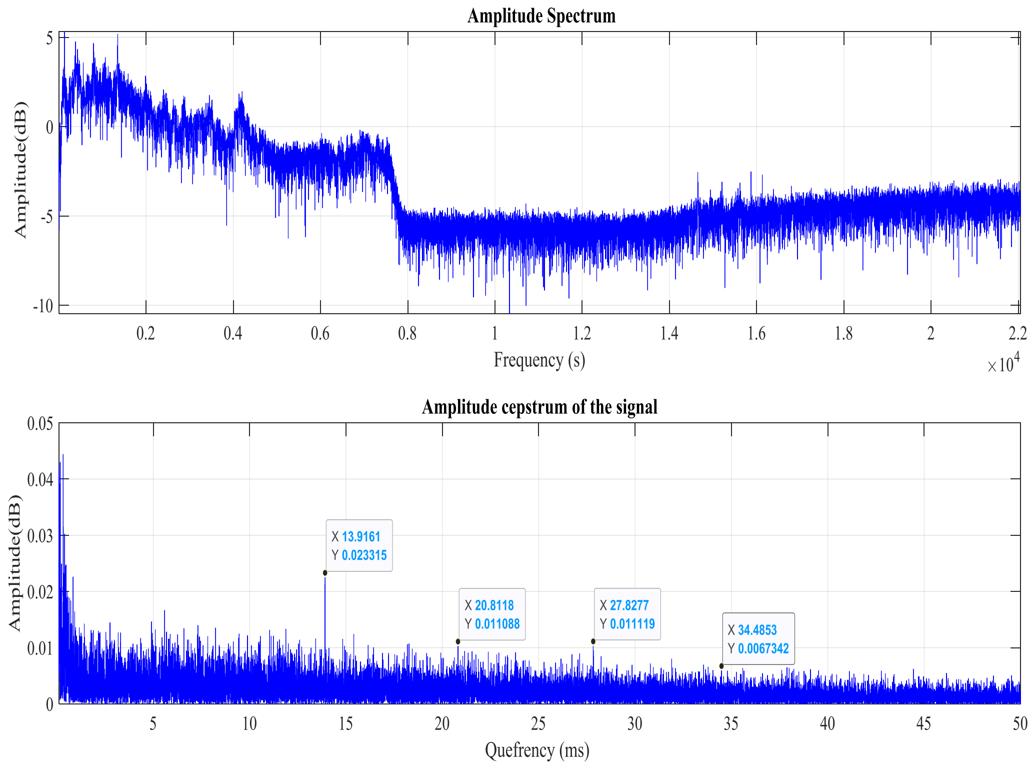

Figure 4 Amplitude Spectrum and Amplitude of Cepstrum of 1-pauk1 note

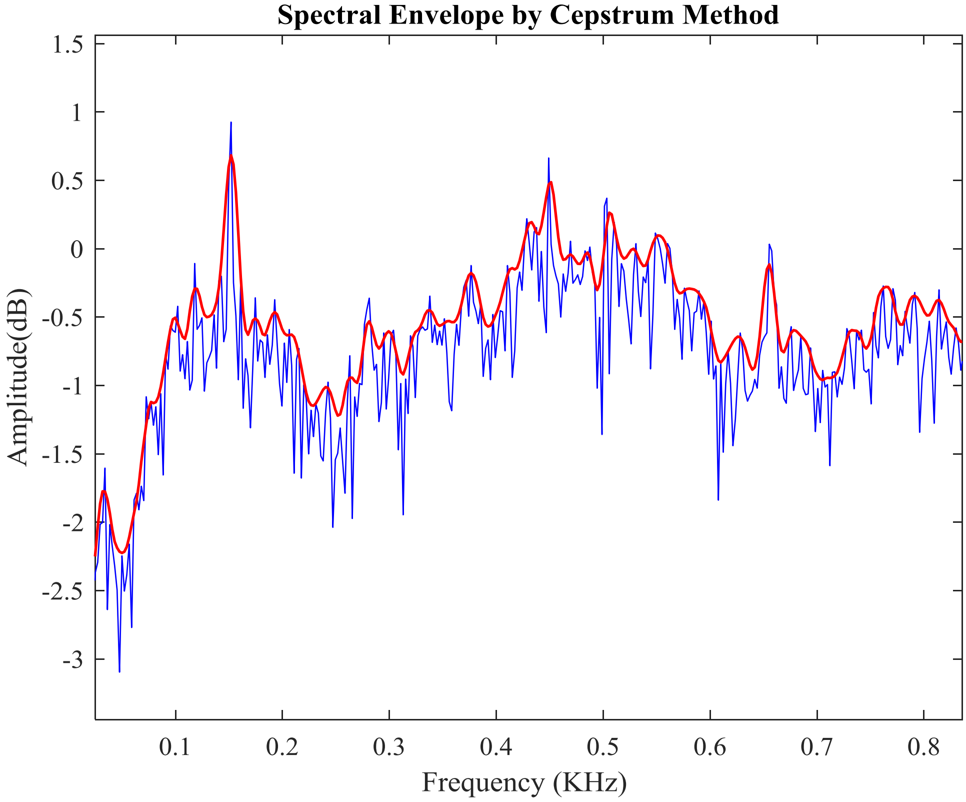

Figure 5 Spectral Envelope of 1-pauk1 note by Cepstrum Analysis

Conclusion

Although the music scale of the middle octave of three different Pattalars is varied in the range between musical significant pitch changes, less than a quarter tone, some of the notes of lower and upper octave are varied close to a semitone. Therefore, the tuning of bamboo Pattalar is not consistent. Quefrency domain represents periodic structures of logarithmic spectrum and thus an accurate indication of the harmonic spacing. Therefore the effect of harmonic family can be study clearly in cepstrum. Cepstrum components are manily lying in the low quefrency parts by shortpass lifterring each of the spectra. And only formants are left in the cepstrum. Therefore separated source and transmission path effects by quefrency contents are also one of the applications of the cepstrum. Spectral envelope can be used as filter coefficients for time-domain filtering and as a transfer function for frequency-domain filtering. It is also the important parameter to control the amplitudes of the partials for resynthesis.

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