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Microtone Analysis of Blues Vocal

- Can Hatsune-Miku sing the Blues? -

Masaki Hayashi Steven Bachelder Masayuki Nakajima

Uppsala University, Campus Gotland
masaki.hayashi@speldesign.uu.se

Abstract

Microtone music is made up of intervals not found in the Western equal-tempered 12-tone scale. This paper describes an attempt to analyze blues vocals originated in US during the early twentieth century and to then represent the vocal line electronically based on this analysis. We have used recordings from the famous blues singer Robert Johnson from 1936 and 1937 and have measured the frequency of his vocal line to determine the difference between the result and the 12-tone scale. By doing so we have obtained the musical notation in microtones. We were then able to re-create the vocals by using a digital sound generator in an attempt to produce a precise replica of the original vocal line. Our final goal is to explore how microtonal singing may evoke ethnic sounding music and corresponding emotional responses in listeners. In addition, we aim to open up the field of synthesized vocal music such as "Hatsune-Miku" towards the worldwide ethnic music beyond the Western 12-tone music.

1. Introduction

Most modern music is composed and played in the equal-tempered 12-tone scale (hereafter, 12-tone scale). This 12-tone scale is made by equally dividing one octave into twelve intervals. On the other hand, the Blues music originated in US early twentieth century has a specific musical scale called "Blue note". It is well known that some notes on the blue note scale are beyond the 12-tone scale. The interval of less than a semitone used in the blue note is called 'Microtone' and music using microtones is referred to as microtonal music.

In this paper, we focus on the blues vocal in particular and attempt to measure microtones in their accurate frequencies as they occur in the melody of the song. Next, we determine the microtonal difference between the measured frequency and the 12-tone scale and thereafter transcribe the corresponding musical notation. Based on this notation, we then re-create it with electronic sound, which is then used to evaluate the result of the analysis.

This research is in its primary stage. Our final goal is to examine a hypothesis that singing in microtones may evoke emotion while hearing the Blues music. We also aim to expand the field of synthesized vocal music beyond the Western 12-tone music in able to include worldwide ethnic music and the Blues.

2. Blues and microtone

Blues music originated in US about one hundred years ago. The roots of the Blues dates back to African music and African-American people coming to America. On the other hand, the Western 12-tone music dates back several hundred years ago. Since then, it has been used in the majority of western music. Folk music, however, has been developed in local ethnic groups aside of the modern society. It then naturally has a distinct musical characteristic not found in the modern music. One of the defining characteristics is the microtonal interval, which are not tempered by an equally divided 12-tone scale. Examples of the well-known microtonal music are Gamelan music in Indonesia, Indian music, African folk music, etc. The Blues whose roots are from African folk music is also composed and played in the microtonal musical scale.

3. Objective and related work

This research focuses on blues vocals and measures the melody line in the precise frequency and precise timing of each note. Based on this measurement, we analyze it in comparison with the 12-tone scale in order to study how microtones are used in the vocal line of blues music. In addition with the vocal line analysis, we attempt to create a precise replica of the original melody reconstructed by electric sound.

There is a related work done in 1998 by Monzo. [1] He transcribed a Robert Johnson's song into microtones by ear and made a MIDI sequence based on his analysis. In our study, we improve the accuracy of frequency by using speech signal processing technology. We also measure the exact timing of each note where the previous work did not. Finally, we will develop this work further widely by providing new opportunities in applications in synthesized vocal music and more.

4. Method

This chapter explains the research. We take one of the pre-war blues singers: "Robert Johnson" as the target of analysis. This is motivated by the following reasons:

- He played in 1936 and 1937, which is the period shortly after blues music was popularized, thus his recordings contain much of the original traits of folk music.
- He is one of the most famous pre-war blues musicians, thus his vocal performance is superior.
- It is relatively easy to analyze the vocal part because he only accompanies by his acoustic guitar.

We use his song called "Me and the devil blues" which is from his recording in 1937 [2] and analyzed the first chorus of the song.

We describe the method of microtone analysis and electronic reproduction of the song below.

(a) Frequency measurement

We use a speech signal-processing library: 'VoiceBase' [3] made by Animo Inc. It uses the 'Mel-frequency cepstrum' method [4] to determine the primary frequency of a speech signal. It gives the frequency of the input speech signal in an interval of 10mS, which is enough to obtain the melody line. Fig. 1 shows an excerpt from the measurement with VoiceBase. We have confirmed that this can work for vocal line analysis. Owing to this technology, we have been able to dramatically improve the accuracy and efficiency of the measurement.

(b) Musical notation

We developed a tool for the analyzing process (see Fig 2). The upper part displays a playable original sample signal. By playing back the sample and studying the wave shape, we are able to manually identify a tone of the melody and specify the

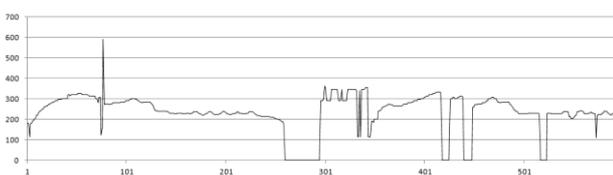


Fig. 1. Result of measurement (excerpt from 2 bars)
Horizontal: Time (mS) Vertical: Frequency (Hz)

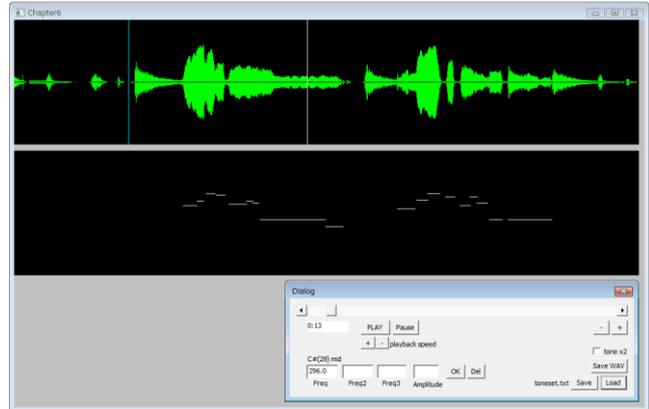


Fig. 2. Microtone notation tool

start and the end time. We are then able to assign the previously measured frequency and finally get a piano-roll notation as seen on the lower part of the window.

(c) Reproduction by electric sound

The tool is able to generate sine-wave signals according to the piano-roll notation. The generated signal is located in right channel and the original tune is located in left channel.

(d) Microtonal notation

The piano-roll notation represented in frequency is converted to an interval name with the difference from 12-tone scale. The relationship between the measured frequency 'f (Hz)' and an interval number 't' (0: root, 12: one octave) from the root note whose primary frequency is 'f0', is as follows:

$$\frac{f}{f_0} = 2^{\frac{t}{12}}$$

When a unit 'Cent' which is a 1/100 of a semitone is used, an interval can be represented by a value of a cent multiple of 100 as shown in Table 1. When the primary frequency f0 is 440Hz (Key of A), we can obtain the interval name plus the difference from the 12-tone interval in a value of cent using the above formula.

Table 1. Tone name and cent

tone	A	A#	B	C	C#	D	D#	E	F	F#	G	G#
cent	0	100	200	300	400	500	600	700	800	900	1000	1100

5. Experiment result and discussion

Table 2 shows the result of measurement. The data consist of 'frequency (Hz)', 'starting time of the note (second)' and 'duration (second)'. The measured key of the song is 230Hz by analyzing the accompanying guitar. The key is a bit lower than

Bb (233.08Hz) when A=440Hz. However, we will discuss the result in key of A which is the key frequently used in the blues by transposing the original key 230Hz to 220Hz (key of A).

Table 2. Result of measurement (excerpt of 2 bars)

Note number	Frequency (Hz)	Starting time (s)	Duration (s)
0	275	11.998	0.217
1	290	12.215	0.113
2	320	12.360	0.150
3	313	12.520	0.140
4	280	12.720	0.295
5	290	13.005	0.105
6	285	13.105	0.095
7	231	13.220	1.055
8	213	14.270	0.285
9	266	15.420	0.160
10	266	15.570	0.130
11	296	15.730	0.180
12	320	15.900	0.210
13	307	16.190	0.150
14	275	16.420	0.170
15	307	16.580	0.120
16	285	16.690	0.175
17	231	16.895	0.205
18	231	17.190	0.705

The accuracy of the frequency measurement is approximate 2 to 5 Hz due to the accuracy of the signal processing. Thus, it is equivalent to approximate 1/10 microtone of a semitone.

Fig. 3 shows the musical notation represented with microtone after transposing the key to A=220Hz. Looking at the notation,

we can observe that the root note (A=220Hz) is sung exactly, however, all the notes except the root are sung out of the equal-tempered 12-tone scale. It occasionally reaches almost more than 50 cents (1/2 semitone). It is difficult to state whether he sings a certain microtonal note higher than the exact 12-tone or lower than the one step upper tone. (eg. C (65) or C# (-35)). We set up the border at 70 cent when the tone is signified on the notation. It is often said that the distinct feeling of the blues music is characterized by so-called 'Blue-3rd', which lies approximately halfway between the major 3rd and the minor 3rd. By observing Robert Johnson's singing, however, we find it is more complicated. In the key of A, the blue-3rd is between C and C#. Johnson sings this tone in various intervals with microtone 1, 33, 63, 93 cents. It varies widely. As seen on the notation, there are many microtones other than the blue-3rd. This indicates that Johnson sings in a more organic way than a formalized way.

By listening to the reproduced electric replica of the vocal, even though it may be subjective, it seems to have the distinct feeling of the original vocal line. We have also made the guitar accompaniment using MIDI sound. We transcribed his guitar play precisely and generated the guitar section mixed with the

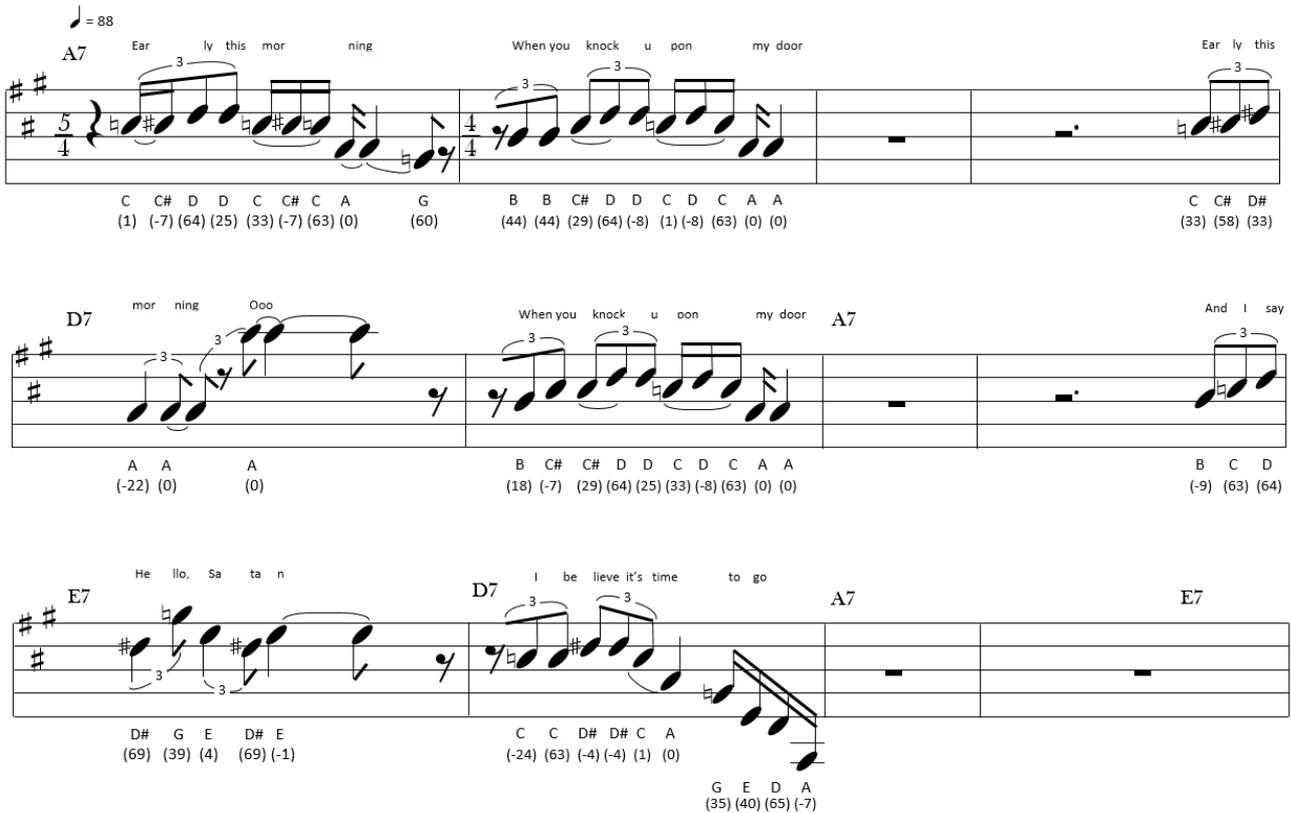


Figure 3. Musical notation with microtone of the vocal of 'Me and the devil blues' by Robert Johnson (recorded in 1937).

- Transposed to 'key of A' from the original key 230Hz (a bit lower than Bb)
- Microtone is noted in bracket. Unit is 'cent' (1/100 semitone)
- Timing of the note has been quantized although the actual timing in the original is fluctuated.
- G-clef is omitted.

electric vocal to get the final electric replica of the song. The guitar play is performed in exact tempered 12-tone scale and exact rhythm of 'Shuffle'. The subjective impression of the electric play is that: it sounds like the original 'twisted-like' impression even though it is just a sine-wave signal, and the contrast between the twisted-like impression and the sine-wave-based electric sound produces a certain uncanny feeling.

6. Conclusion

Microtone analysis of blues vocal is presented. We took a song recorded in 1937 sung by Robert Johnson. We measured the vocal line in frequency with an accuracy of 1/10 of a semitone and identified the microtonal difference from equal-tempered 12-tone music system. We also recreated the replica of the original in electric sine-wave sound mixed with the guitar accompaniment made using MIDI sound. Finally, a complete representation of the original is created in an electronic form.

Based on the analysis, we revealed that Robert Johnson sang a blues tune in microtonal intervals, which are out of the 12-tone scale except for the root note. From the subjective impression of listening to the reproduced electronic sound, the characteristic strange 'twisted and fuzzy' feeling that the original vocal had, can be verified to some extent.

This research has just begun. We have many challenges for the future. To begin with, more samples will need to be analyzed so that we can compare each sample to arrive at unified characteristics. We will also need to modify the obtained microtonal musical notation to get forcedly tempered intervals and to examine the impression compared to the original. We will also examine a time-wise fluctuation of the melody.

Although our reproduced electric replica was made with sine-wave signal and MIDI, we will use vocal synthesizer such as Vocaloid (Hatsune-Miku) [5] to sing the exact microtonal melody with lyrics. Rock music was originated by Blues and a

big part of the modern Pop music is Rock music. We can say that the microtonal way of singing is a significant factor that makes Rock music sound 'Cool'. The current Vocaloid is good at singing well-tempered pop music but is weak in Rock & Roll. Thus, this research is expected to proceed towards the challenge to open up the field of synthesized vocal towards new types of music. In a mean time, we will see Hatsune-Miku sings the real BLUES.

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