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Khaen sound synthesis using a subtractive method

Kittipitch Meesawat*

Department of Electrical Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen 40002, Thailand.

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Abstract

This article presents a khaen sound synthesis using subtractive method with presumed input signal. The presumed signal was sawtooth wave which contains strong harmonics at low frequency and rolled-off harmonics at high frequency. This allows a lower order filter design. The subtractive filters were 50th order infinite impulse response (IIR) filters designed from 8191st order finite impulse response (FIR) filters impulse responses, which were designed based on different between magnitude spectrum of the target sounds and that of the corresponding sawtooth wave. A realtime implementation on Csound was also presented. The quality of the synthesized sound still needs improvement.

Keywords: Khaen, Sound synthesis, Subtractive method, Csound

1. Introduction

Khaen is a common aerophone instrument in northeastern part of Thailand and in Lao People's Democratic Republic (LDPR). It is categorized as an asian free reed bamboo mouth organ instrument [1]. The instrument consists of a wind chamber, called “tao khaen”, inserted with two rows of 8 bamboo resonator pipes, called “sang khaen”. Each resonator is mortised and coupled with a thin metal reed. A resonator pipe can produce only a single pitch and is controlled by finger holes located just above the chamber.

Khaen is widely used in many genres of local music in the northeastern area of Thailand. Khaen sound synthesizer would allow ease of practicing without distrubing neighbour and new possibilities in music creativity. It could also make a public address of khaen sound easier.

2. Subtractive filter design

There are several synthesis methods in musical acoustic, e.g. additive method, subtractive method, digital waveguide, and physical modeling [2]. The subtractive method were chosen because of its simplicity in both design and implementation. Usually, the input to the subtractive synthesizer is either pulses train or white noise. The subtractive filter removes the unwanted frequency content from the input signal. From the khaen sound waveform, it can be presumed the sawtooth wave as an input signal. Since the input signal already has strong harmonics at the lower end and rolled-off harmonics at the higher end, the subtractive filter does not have to do much attenuation at the higher end, nor to take care the vellays of the frequency content of the signal. It is also easier to make a connection between this sawtooth wave and physical parameters of the real instrument. Figure 1 depicts a conceptual block diagram of the synthesizer employed in this article.

The khaen synthesizer design consists of two stages, the khaen sound analysis to acquire the first formant frequency of each pitch, and the subtractive filter design based on the different between spectrums of the khaen sound and that of the corresponding sawtooth wave.

2.1 Measurement and analysis

Because compromising on pitch frequencies among different substances of khaen could lead to unrealistic pitch frequencies, so only one good silver reed khaen was chosen as a prototype. The measured sounds were taken from [3]. The measurement setup is brifely as followed. The resonator

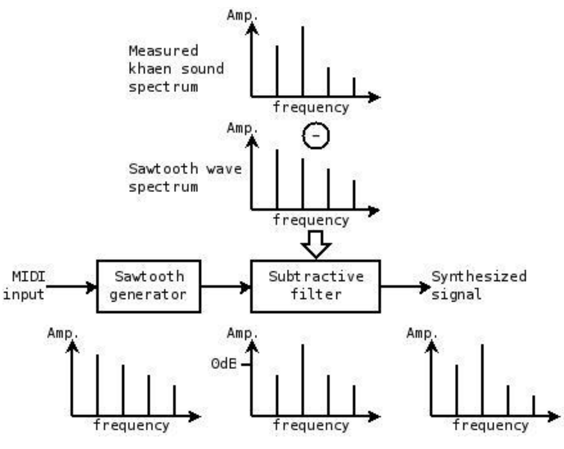

Figure 1 Conceptual block diagram of the subtractive khaen synthesizer

*Corresponding author. Tel.: +6683 413 3106
Email address: mkittiphong@kku.ac.th
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Table 1 Khaen first formant frequencies

Resonator	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**
Frequency (Hz)	522	247	294	331	348	393	693	782
Resonator	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Frequency (Hz)	221	262	391	442	494	590	661	877

was inserted into an air chamber which its inlet was supplied by a controlled compressor. The generated sounds and the supplied pressures were captured using a dynamic microphone and a differential pressure sensor, respectively. All acquired data were stored in a PC with a sampling rate of 48 kHz.

Power spectrum density of sound generated from each resonator were determined using Welch's method [4] to find the first formant frequency. The Blackman-Harris window with 48000 points was used, the overlap was 50%. This makes the frequency resolution to 1 Hz. The analyzed signals were approximately 10 seconds long. The first formant frequencies of khaen pipes are listed in Table 1. The label L1 was designated to the first pipe (closest to the player) on the left hand and the label R8 was for the eighth pipe (furthest to the player) on the right hand side of the khaen player.

2.2 Filter design

The desired frequency response of each synthesis filter was acquired from the differences between the spectrums of the khaen sound and that of the corresponding sawtooth waveform. Because most energy of the sawtooth waveform is distributed to fundamental and harmonics, the filter magnitude gains were specified only at these frequencies. Figure 2 clarifies the above concept.

The filter design in this article follows an approach presented by [5], i.e. determine a high order finite impulse response (FIR) filter from the desired frequency response using the frequency sampling method, then estimate a lower order autoregressive (AR) model of the FIR system using Yule-Walker method. The obtained AR model were then used as an infinite impulse response (IIR) synthesis filter. The order of the FIR and the IIR filters used in this article were 8191st and 50th order, respectively. The order of the IIR filter was limited by the Csound implementaion. Figure 3 shows the desired frequency response, and the frequency response of the FIR filter, and that of the IIR filter. The differences between the real and the synthesized sound are, however, perceptible.

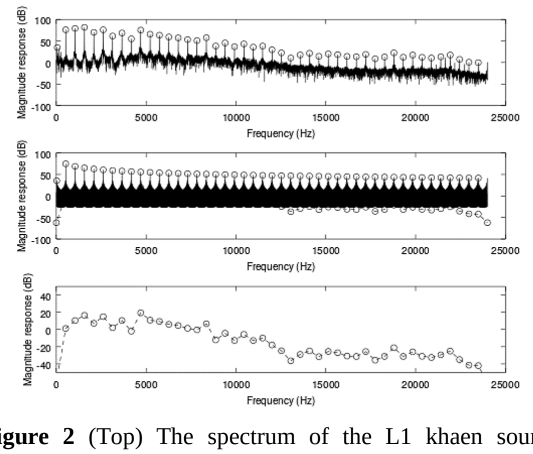

Figure 2 (Top) The spectrum of the L1 khaen sound, (Middle) the spectrum of the corresponding sawtooth waveform, and (Bottom) the desired frequency response of the synthesis filter.

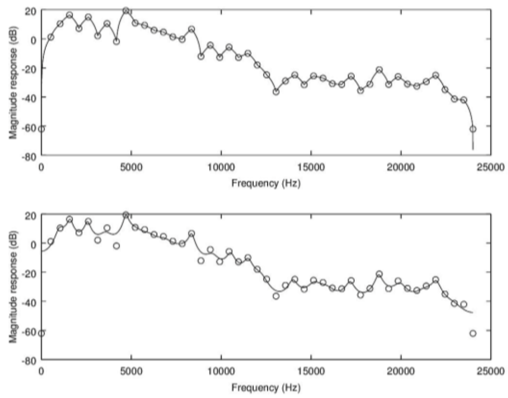

Figure 3 (Top) The desired frequency response of the L1 synthesis filter ("o") and the 8191st order FIR filter frequency response, and (Bottom) the 50th order IIR filter frequency response.

3. Csound implementation

Csound is a tool to creating and processing sound [6]. Users write a Csound file containing the instrument definitions and the music definitions. Then ones can call the Csound file using Csound command. It can be integrated into various programming languages, e.g. C and C++ using Csound API. A simpilied Csound flowchart are presented in Figure 4.

The musical instrument digital interface (MIDI) input used in this article was a generic MIDI controller keyboard. The MIDI numbers were subtract by a MIDI offset and became the first formant frequency table index. The offset was 57 which is the MIDI number of the 4th A (A4). This offset can be changed to suit any particular MIDI controller.

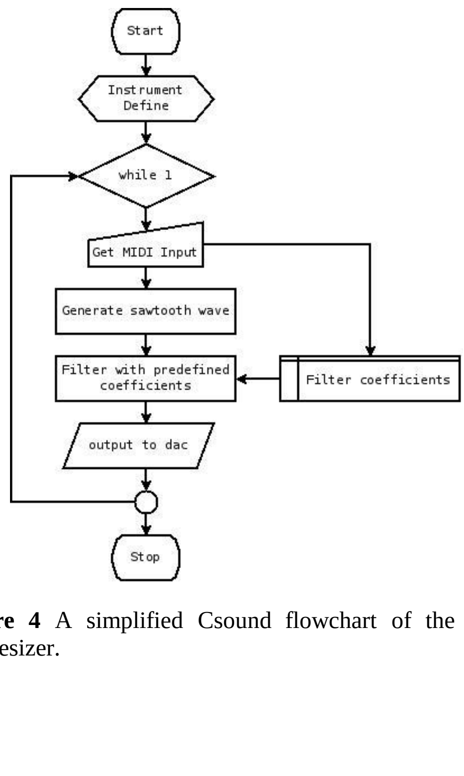

Figure 4 A simplified Csound flowchart of the khaen synthesizer.

The frequencies in the table noted the fundamental frequency of the generated sawtooth wave. The table indexes were use for selecting the right synthesis filter for each khane pipe.

4. Discussion

The goal of this project was to implement the synthesis filter on a realtime platform using Csound, thus the order of filters were then limited to 50. Even though cascading filters could allow higher order filters implementation but it comes with a longer latency time which is critical if this is to be used in realtime by musicians. A warped frequency filter designed as proposed by [5] to reduced the required filter order has been tried, but the direct implementation maked it numerically unstable, therefore it is not reported here. The synthesized sound quality still needs an improvement. This could be because of technique does not take interharmonics that are presented in the real sound into account.

5. Conclusions

A khaen sound synthesizer design using subtractive method was presented. An implementation of the lower order filter was accomplished by the presumed input signal. The synthesizer was implemented on a personal computer using Csound. To make a useful system with high mobility, an implementation on a signale board computer such as the Raspberry Pi is possible.

6. Acknowledgement

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7. References

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