AUTOMATED CHINESE TRADITIONAL CHIMES WITH SONG

By

Luting Lei

Siyi Li

Tianle Wu

Xiaoxiao Pan

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Contents

1. Introduction

1.1 Problem

Few people play Chinese traditional Chimes, and they're often stuck in traditional music, which seems to be a barrier of traditional instruments. Additionally, the lack of research on blending modern music with Chinese traditional genres is another challenge. By addressing these issues, the project contributes to the inheritance of Chinese culture in a modern context and innovatively researches the possible music style transformation between model music and traditional Chinese music. However, the chimes we can find can't meet the requirement of being able to play, out of tune and too widely spaced.

1.2 Solution

The project aims to revive the melody played by smartphones in the Chinese traditional Chimes. We will first recognize a melody from a smartphone and generate the adapted melody for chimes, then transform the melody to signals, and then control a mechanical design to ring the chimes with the motor. We intend to transform the instruments that would have been used to strike the chimes and their control system to control the striking of cups filled with water. Replace chimes that produce different tones with cups containing different amounts of water. The following references to cups filled with water still use chimes.

1.3 Visual Aid

The project aims to revive the melody played by smartphones in the Chinese traditional Chimes. We will first recognize a melody from a smartphone and generate the adapted melody for chimes, then transform the melody to signals, and then control a mechanical design to ring the chimes with the motor. The diagram for visual aid is shown in Figure 1.

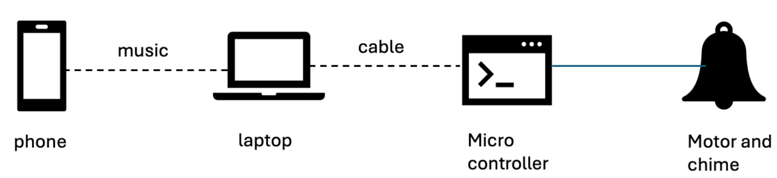

Figure 1 visual aid

1.4 High-level requirements list

1. Training a machine learning model that could correctly recognize the melody from a smartphone (with noise). Apply the algorithm to adapt the recognized melody for chimes play.

2. Generating correct position and time signals and successfully controlling motor operation.

3. Make the adapted music pleasant and make the whole structure as simple as possible.

4. Achieve striking functionality through a structurally simple, efficient, and aesthetically pleasing design.

5. Ensure that the striking method produces a high-quality, crisp, and stable sound from the water cup.

6. Achieve auto-injection function.

2. Design

2.1 Block diagram

The block diagram of our design is shown in Figure 2.

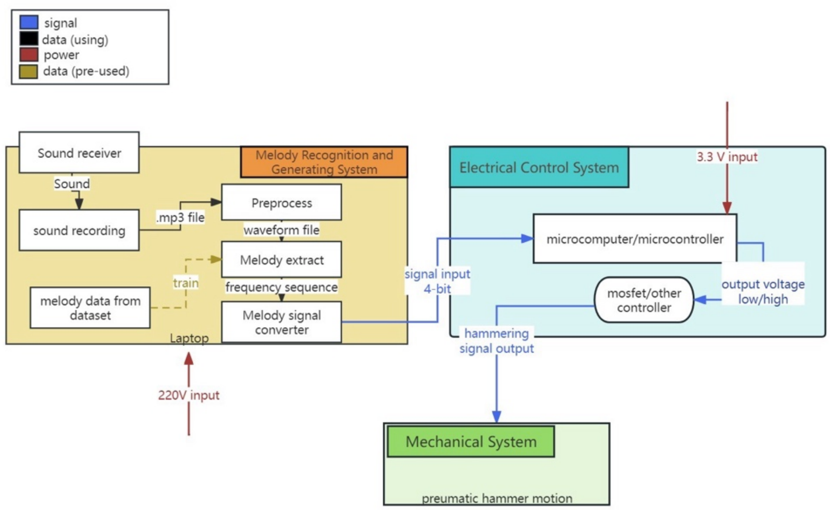

Figure 2 Block Diagram

2.2 Subsystem overview

2.2.1 Melody Recognition and Generating System

The model will be trained to automatically recognize the main melody from a period of sound played by the smartphone and adapt to Chinese traditional style for chimes.

The Subsystem has the following functions:

a. Sound Recording. We will record a 30s long audio through our laptop sound receiver and save it as an audio file. This function serves as the start of the interaction of this project.

b. Preprocess. Then, we will use python to preprocess the audio file, reducing noise and cutting off empty period in the audio. We will detect the volume to determine the effective part we need to identify.

c. Melody Extract. We will identify the melody by extracting the frequency sequence. We will use a combination of signal processing method and data driven method. The process shows as figure below:

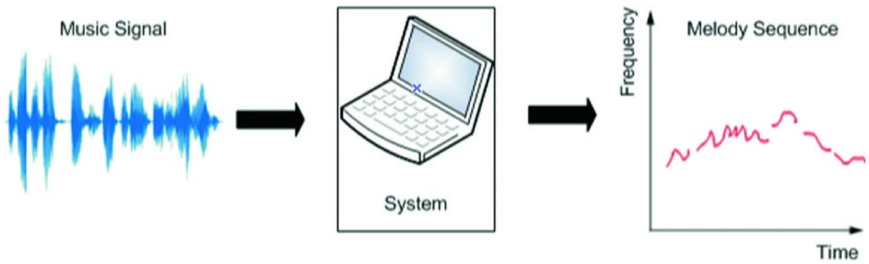

Figure 3 procedure of melody extract

For monophonic melody, we will use simply STFT to get the main frequency with the highest energy each frame, then round the pitch to the standard pitch. For example, A = 442 Hz and we have detected a pitch at 440 Hz, we will round it to 442 Hz. We will also identify the strength by rounding it to four levels to determine how loud we reproduce the song.

For polyphonic songs, we will use a combination of signal processing methods to gain spectral representation and data driven methods, building deep convolutional neural networks to gain final melody sequence. The training data for neural network will be public music recording dataset, here is some related information:

Table 1 information of related public music recording dataset

Name	**Sampling rate (in KHZ)**	**Pulse code modulation (in bit)**	**Genres**	**Duration (in seconds**
MIREX 2005	44.1	16	Rock, Pop, Jazz, Piano	20 - 30
Medley DB	44.1	16	Rock, Pop, Jazz, Piano	-
Medley DB	44.1	16	Daisy, Jazz, Opera, MIDI, Pop	20

These two functions contribute to the project by identifying the melody.

d. Melody Signal Converter. Finally, the frequency sequence will be converted to the signal. With certain interval, pitch frequency, and strength, the information of notes could be proceeded to the microcontroller digitally at certain frequency. This function served as a connection between Melody Recognition and Generating subsystem and Electrical Control subsystem. The signal will be generated only with the position and strength information. Then they will be transmitted to the microcontroller with certain frequency by a USB cable. Based on the information obtained from python, we could generate the control signals for microcontrollers, for example, we have a series of bits, and the first bit represents whether one note should be generated at this interval, then the following 3 bits represents the one should be knocked (8 in total), the following 2 bits represents the strength (4 in total).

2.2.2 Electrical Control System

We will also design a control circuit to transmit signals from the microcontroller to the mechanical part. There are 8 output pins with 3.3V- 5V output as logic “1” and 0V as logic “0”, and the microcontroller is duty for processing the location data and control the voltage at each pin. The pin is connected to the gate of an NMOS, which operates as a switch to control the motor.

2.2.3 Mechanical System

A hammer structure hanging horizontally at the top of a series of chimes (cups) controlled by a motor. It will ring the corresponding chimes controlled by the electrical control system. The primary design is shown below:

Figure 4 Block Sketching of the Mechanical Part

The water will be placed in two parallel lines and the striking part will be arranged between the cups. The motor will serve as the base and control the worm gear (blue part in figure) to rotate. Each motor will control two sticks (green part in figure), which is fixed in position. We apply siphon effect with pipes to achieve the function of automatically filling the water to the right level.

2.3 Subsystem Requirements

2.3.1 Melody Recognition and Generating System

Table 2 Requirement and verification of melody recognition and generation system

Requirement	Verification	Verification Status
1. The environment for using our product should be in a quiet	Procedure:	1. Y

space and the song should be relatively loud. We define –65 db as the sound threshold, which means sound louder than –65db will be considered as the song we want to identify. 2. Considering the data trained for neural network, we also limited the song to be identified within 30s.	(a) Run firstly a program to test whether the audio is good after the audio being recorded. Normal audio should be a period of empty audio – song we want to detect – a period of an empty audio. (b) If the program doesn't detect these two empty parts with volume less than –65 db, then the audio does not align with the requirement. (c) If the program detects these two parts, the audio aligns with the requirement.	
The Program Successfully generate the right frequency sequence	Procedure: The control signal will be generated in particular frequency, especially a couple of times of the detected beat. If the signal showing there is a note appears periodically, it means the beats generation is successful.	2. Y
The chime generates correct notes which performs the regenerated song	Procedure: The melody performed by the chime could also be recorded, and then compare it with that performed by the phone in frequency domain with stft function.	3. Y

2.3.2 Electrical Control System

The system will transform the generated melody to location and time signals (for different pitches and rhythms) and build a microcontroller.

The plan is to use a microcontroller to convert the input signal (4-bit signal) into a switch to control the circuit, and to control the thyristor to realize the circuit on and off. By connecting twelve mechanical hammers to each of the twelve circuits, the signal input to the mechanical part of the conversion is realized by using controllable thyristors such as MOSFET or IGBT to control the on-off time of the circuit. The control voltage of the microcontroller is in the range of 3.3-5V, and the control voltage of the controllable thyristor is controlled by the output of the microcontroller.

The outside circuit will include about eight MOSFET and several resistors to protect the whole circuit.

Table 3 Requirement and Verification of Electrical Control System

Requirement	Verification	Verification Status
1. Processing the input signal and then getting the	To be specified, we plan to use the whole microcontroller system, including clock, LEDs, chips. (As figure 5 shown) The part we plan to use are listed below:	Y

output voltage from the microcontroller system. 2. Using the voltage signal, including the message of time and which pitch the machinal damp will strike, to control the machinal part.	#6: 4*4 matrix button, for simple testing before connected with algorithmic component, using button to control the signal directly. #15: ADC/DAC model, generate signals and control the output voltage. #21: STC89Cxx MCU, processing the input signal and set signal to be 2 parts, 2 bits for striking frequency control and the other 3 or 4 bits for pitch control, and then send them to different processing chips. #19: DS1302, clock used to control striking frequency, getting signals from #21 MCU and then send signals to #15 ADC/DAC model. #20: Stepper Motor Drive Module, probably controlling the striking motor.	
	For the outside circuit: Plan to use some MOSFET or IGBT, the number of them are equals to the number of pitches we need. MOSFET or IGBT are considered as controllable switches, maybe consider using a PCB board to make the whole circuit, since the number of them is quite large and other capacitors and resistors are also needed to protect the whole circuit. (figure 6 is the sample MOSFET control circuit, figure 7 is the sample PCB layout for 8 hammers)	

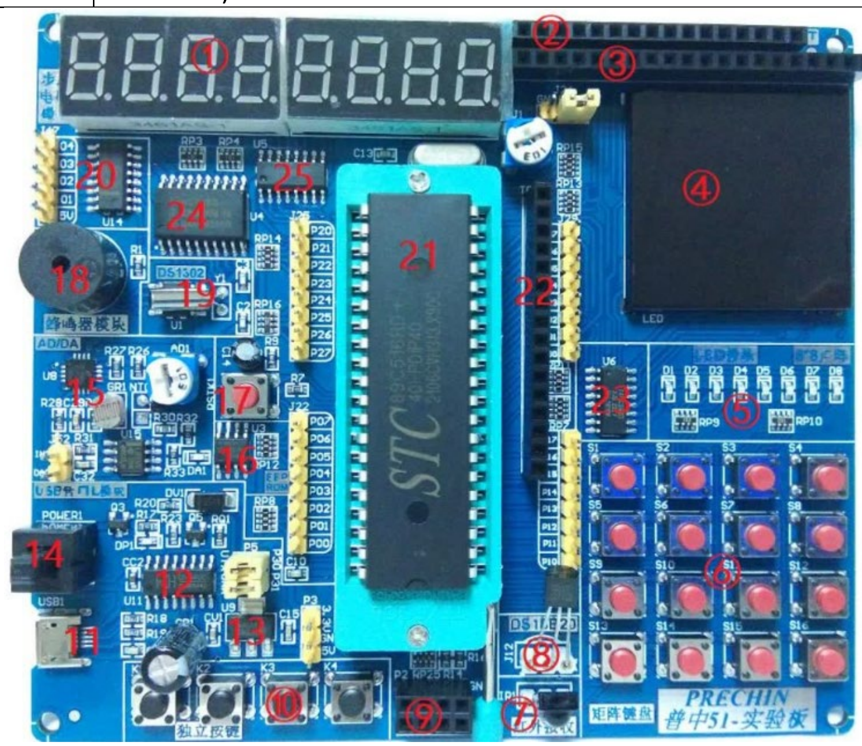

Figure 5 microcontroller system board

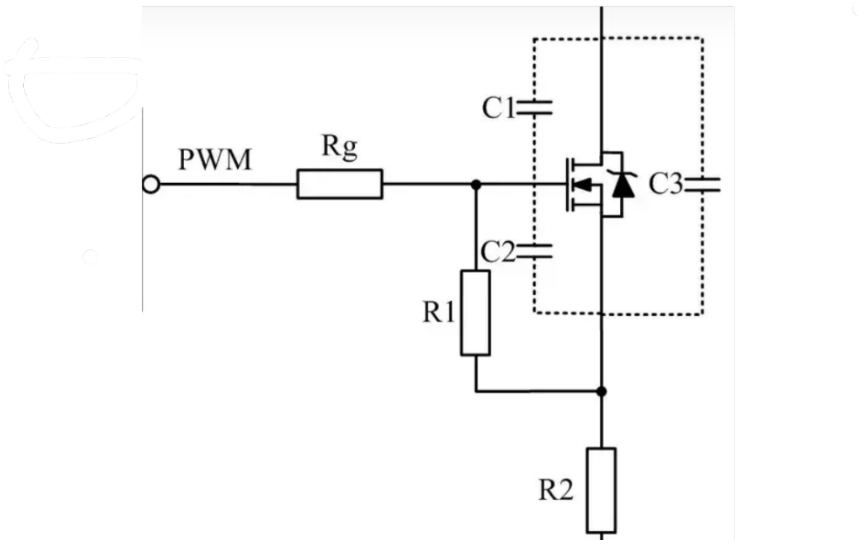

Figure 6 sample MOSFET control circuit

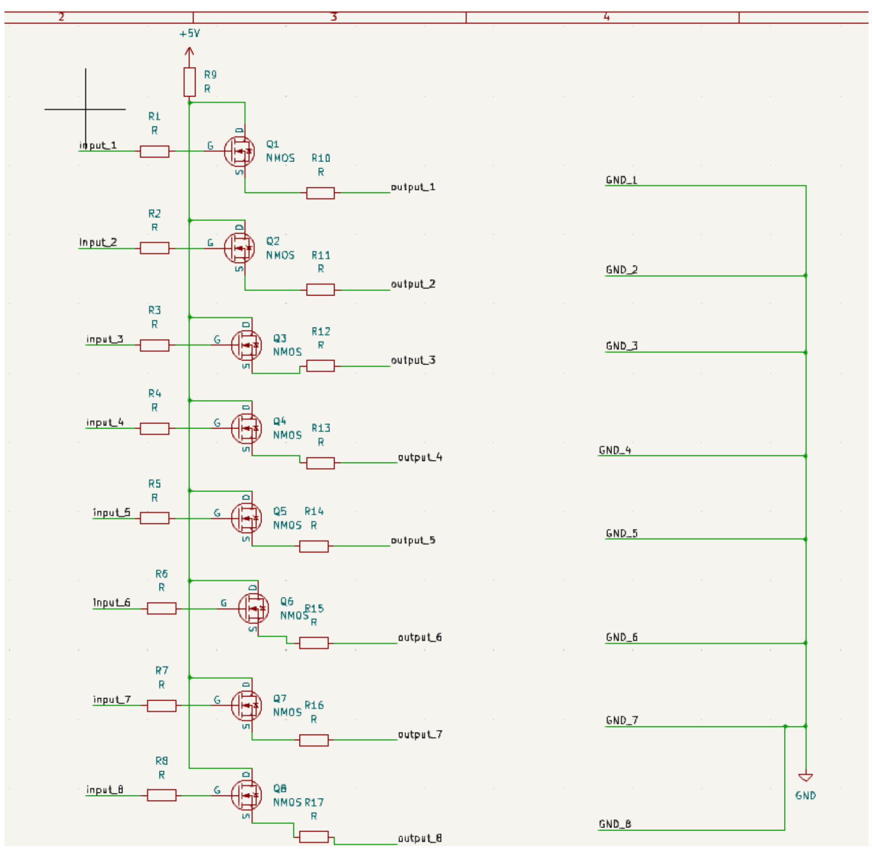

Figure 7 sample PCB layout

2.3.3 Mechanical System

The main structure consists of a frame, a driving motor, and drumsticks. For aesthetic and practical considerations, the motor will be positioned between two rows of water cups, with one motor controlling two drumsticks, aiming to reduce the number of motors and the weight of the structure.

For the percussion structure, we will employ small-sized direct current (DC) low-speed motors for driving. The speed is around 50 rpm. Power Subsystem should contain relays, pulse control instrument and PLC, and be able to supply the rest of the system continuously at 5V ~12V.

To ensure crisp and stable tapping sounds, we intend to utilize wooden rods as the material for the drumsticks, driven by a worm gear mechanism. The hammer should provide at least 5 N·m exciting force. The drumstick should be well controlled after the first strike to avoid redundant strike. We will control the signal time-step or the power supply time-step to limit the phase change of the stick.

Additionally, we utilize the siphon effect to add an automatic water filling function to the water cups.

2.4 Tolerance Analysis

At the moment, based on the materials we have purchased, the chimes themselves do not have the intonation we would expect, and to a certain extent they are not even playable in their entirety; the pitches the twelve bells can produce are not fully recognizable by professional software and are in a range of fluctuations that are not fully under control.

The rest of the error may arise in the following parts:

1. Recognition of known songs.

2. Delay in hitting the hammer due to variations in signal transmission.

3. Loosening may occur, necessitating regular maintenance, due to frequent tapping and the connections between different materials.

3. Cost and schedule

3.1 Cost analysis

Table 4 Cost Analysis of Labor

Name	Hourly Rate	Hours	Total	Total x 2.5
Tianle Wu				
Luting Lei				
Siyi Li				
XiaoXiao Pan				
Total				

Table 5 Cost Analysis of Materials

Part	Cost (prototype)	Cost (bulk)
Microcontroller system	￥70	￥70
Traditional Chinese Chimes	￥88	￥88
Cups	￥48	￥16 per 6 cups
Pneumatic hammer	￥10	￥10
fastening	￥200	￥200
Motor and battery	¥100	¥15 per motor set

3.2 Schedule

Table 6 Schedule

Time\group task	Luting Lei &Tianle Wu (Algorithmic signal control)	Siyi Li & Xiaoxiao Pan (mechanical control)
Week 6	Finish the pipeline to generate signal for microcontroller, develop algorithm of monophonic as baseline	Testing on whether the Chimes can be used to perform, otherwise using some other objects like cups with water to replace.
Week 7	Continuously develop algorithms of more complicated melody extraction	Adjusting the instrument we decide to work on, including the intonation and the force that needed to strike.
By April 15th	Optimize algorithms and research on melody recompose	Try to connect the microcontroller with the designed circuit and the mechanical part
Mid-test	Testing on doing simple melody on the cups controlled by electronical part	
By end of April	Develop melody recompose to adapt for chimes	Use a microcontroller to control the tapping, with the goal of being able to control it to play a simple piece of music.
By the mid-May	Combining the complete two parts for functions: recognition + performance	

4. Ethics and Safety

The IEEE Code of Ethics emphasizes the importance of protecting the public, so we will ensure the entire cups and the mechanical parts of its striking are capable of safe operation. However, there are still the following points worth noting:

1. The overall mechanical part of the false placed on the horizontal surface to prevent accidental fall damage, affecting safety.

2. The whole mechanical structure should be placed in a place that is not easily touched by children, to prevent children from accidentally ingesting or being injured.

3. It may not be suitable for people with impaired hearing to use it, and some of the chimes are too high-pitched, which may cause auditory impacts to some groups of people. When we change to cups with water, we can control the pitch to around C3-C4, not too high for people to preform.

4. The primary ethical concern would be ensuring the safety of individuals interacting with the structure. If the striking mechanism is too forceful or unpredictable, it could cause injury to users or bystanders. Improper tapping technique and force may cause the glass cups to topple, potentially resulting in dangerous glass shards and injury incidents.

5. Consideration should be given to potential malfunctions of the striking mechanism. For instance, if it is used inappropriately or lock itself, it could lead to unintended damage or harm.

References

[1] IEEE. (2024). IEEE Code of Ethics. Available at: https://www.ieee.org/about/corporate/governance/p7-8.html. Accessed March 2024.

[2] alldatasheet.com. (n.d.). *STC89C52 Datasheet, PDF*. Alldatasheet. Available at https://www.alldatasheet.com/view.jsp?Searchword=STC89C52