Collaborative Musical Performances with Automatic Harp Based on Image Recognition and Force Sensing Resistors

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ABSTRACT

In this paper, *collaborative performance* is defined as the performance of the piano by the performer and accompanied by an automatic harp. The automatic harp can play music based on the electronic score and change its speed according to the speed of the performer.

We built a 32-channel automatic harp and designed a layered modular framework integrating both hardware and software, for experimental real-time control protocols. Considering that MIDI keyboard lacking information of force (acceleration) and fingering detection, both of which are important for expression, we designed force-sensor glove and achieved basic image recognition. They are used to accurately detect speed, force (corresponding to velocity in MIDI) and pitch when a performer plays the piano.

Author Keywords

automatic harp, force sensing resistor, image recognition, collaborative performance

CCS Concepts

•**Human-centered computing** → *Collaborative interaction; Graphics input devices;* •**Computer systems organization** → **Robotic components;** •**Hardware** → *Sensors and actuators;*

1. INTRODUCTION

What we want to do is to let the robot play the specified music along with the performer, which means that the robot needs to know which part of the score the performer is playing, the speed and mood of the performer. For primary experiment, we designed force sensor glove and used image recognition.

2. RELATED WORK

2.1 Automatic Instruments

Automatic instrument is defined as a specific kind of automatons that can play music. In 2004, Dannenberg invented a McBlare bagpipe robot which can play music beyond human ability, even identify gestures of people and improvise [2].

In recent years, various automatic instruments have used force sensors, cameras to extend the form of collaborative performance [4]. Also, historical rehearsal data has been utilized to improve the expressive performance of the automatic music instruments [6].

2.2 Force sensor

Force sensing resistors (FSRs) have been widely used in system design of historical NIMEs such as drum-pad controllers to get key pressure information [5].

Tangible tabletop instrument developed by Bosi and Jordà explores gestures for musical expression such as continuous finger/hand pressure and percussive impacts [1].

3. SYSTEM DESIGN

We built the whole system covering the hardware and software for experimental real-time control protocols and collaborative algorithms.

3.1 Mechanical Design

The body of the harp is made of aluminum profiles and other accessories are made of plexiglass panels. 16 strings on each side are arranged in semitones (Fig. 1).

Each channel consists of a string, a tongue and the electromagnet that pulls the tongue to pluck the string. The crankshaft is used to bring the tongue back to its rest position after the electromagnet is discharged. The volume is determined by the length of the tongue in contact with the string that is adjusted by the stepped motor.

The circuits are controlled by an Arduino board. There are three types of events for each channel: turning on/off the electromagnet, turning on/off the stepper motor, and switching its direction. Since the ports in Arduino Uno is not enough to accommodate all the 96 outputs, we cascade 4 shift registers 74HC595 for serial-to-parallel conversion.

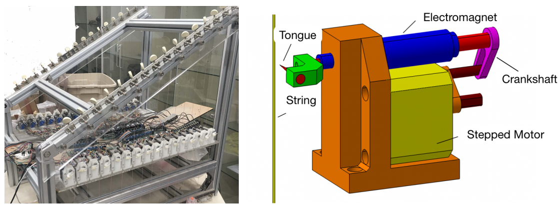

Figure 1: Automatic harp and operating mechanism inspired by harpsichord

3.2 Force Sensor Glove, Image recognition

3.2.1 Glove design

One advantage of using force sensors is that before we hear the sound of a note, the action of pressing will be detected.

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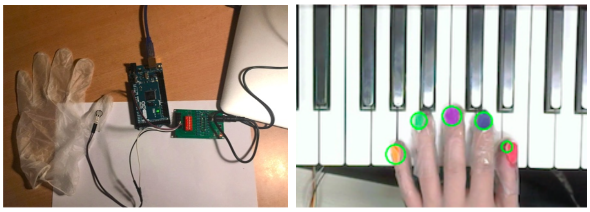


Figure 2: The force sensor glove and Image recognition using RGB camera

The force sensor glove consists of FSRs, rubber glove, a voltage divider circuit and an Arduino board. FSRs are stuck to the fingertips of the glove (Fig. 2). FS-C10 is chosen because the size (10 mm) is close to the size of fingertip, cheap (3 dollars each), and sensitive in the range of 200 to 2000 grams.

Once the performer presses down, the change in resistance is converted to a voltage change by the voltage divider circuit, which will be detected by the Arduino Board.

3.2.2 *Image recognition*

The RGB camera is used to position the finger. The piano keys are divided by the interval between them. Each fingertip of the glove is painted in a different colour. Once we know which finger has pressed the key, we can easily locate it by finding the centre of the corresponding colour (Fig. 2).

Through this visual interface, automatic marking of the fingering can be accomplished by painting the finger and associated keys in the same color based on electronic scores.

3.3 Controlling framework and algorithm

The upper software is written in Python and integrates network communication, signal processing and collaboration algorithms. Based on the traditional real-time score following algorithm [3], we utilized it by using bar-to-bar comparison for human-computer performance, which means comparing the speed of one-bar notes after getting the sufficient number of notes.

4. EXPERIMENT

4.1 Collaborative Performance

The collaborative performance was conducted as follows: the player played the left-hand part of the piano score, Two Tiger, and the automatic harp played the right-hand part. The system calculated the speed of first bar, and automatic harp started at corresponding speed.

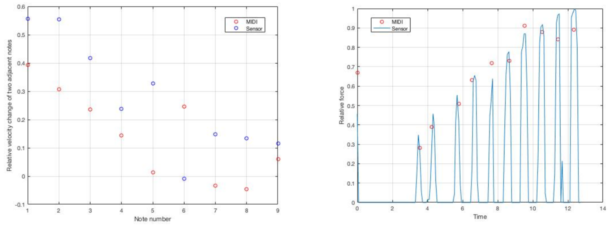
When performer tried to change the velocity, even played the wrong notes, the system could adjust the changes and accompany the performer well.

4.2 Velocity Detection

We played a series of notes and gradually increased the force. The velocity of the note was detected by the force sensor glove and the MIDI port. By comparing the relative forces by dividing the respective maximum value, we can say that force sensor gloves can accurately detect velocity information (Fig. 3).

The relative velocity change of two adjacent notes using the force sensor glove is greater than that using the MIDI port, indicating that the force sensor glove has at least the same accuracy as the MIDI port.

For most notes, the pressure rises earlier than the note time output via MIDI, which provides us a chance to detect the press. Even when the finger is pressed quickly, the full width at half maximum exceeds 0.2 seconds (Fig. 3(b)).



(a) Relative change (b) Relative force

Figure 3: Relative forces and changes of two adjacent notes through force sensor glove or MIDI port

5. CONCLUSIONS AND FUTURE WORK

We designed a complete system including automatic harp, force sensing glove, RGB camera, and related control algorithms. We compared the note information provided by the MIDI serial port and conducted the human-machine collaborative performance.

For further research, better force sensor and glove design are needed to achieve higher detection accuracy, so that this system can be used to reflect and predict performer's emotion in advance, and explore the relationship between various key-touch methods.

Besides, we have designed new operating mechanism to eliminate the percussive sound of electromagnet to improve the timbre of automatic harp and play quieter songs. The automatic marking of fingering will be completed with visual interface.

Machine learning and other apparatus such as electroencephalography (EEG) will be used to improve performance and system.

6. ACKNOWLEDGEMENT

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