Robotically Augmented Electric Guitar for Shared Control

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ABSTRACT

Robotically Augmented Electric Guitar is a novel robotic guitar that establishes shared control between human performers and mechanical actuators. Unlike other mechatronic guitar instruments that perform pre-programmed music automatically, this guitar allows the human and actuators to produce sounds jointly; there exists a distributed control between the human and robotic components. The interaction allows human performers to have full control over the melodic, harmonic, and expressive elements of the instrument while mechanical actuators excite and dampen the string with a rhythmic pattern. Guitarists can still access the fretboard without the physical interference of a mechatronic system, so they can play melodies and chords as well as perform bends, slides, vibrato, and other expressive techniques. Leveraging the capabilities of mechanical actuators, the mechanized hammers can output complex rhythms and speeds not attainable by humans. Furthermore, the rhythmic patterns can be algorithmically or stochastically generated by the hammer, which supports real-time interactive improvising.

Author Keywords

NIME, musical applications of robotics, augmented instrument, actuated instrument, electric guitar

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing, J.5 [Arts and Humanities] Performing Arts.

1. INTRODUCTION

Robotic musicianship is situated between two primary research areas — musical mechatronics and machine musicianship. Musical mechatronics focuses on sound production through mechanical means while machine musicianship develops algorithms for music perception, composition, performance, and theory [1]. Integrating between these two areas, researchers in the field of robotic musicianship design robots with musical intelligence that can algorithmically generate music in an effort expand and enhance the creativity and expression of their human co-players.

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The Robotically Augmented Electric Guitar (RAEG) is designed to incorporate elements from mechatronic instruments and robotic musicianship, exploring the interaction that is situated between playing a passive instrument and performing with a robotic musician. Unlike other mechatronic guitars, RAEG allows a human performer to have full control over the melodic, harmonic, and expressive elements of the instrument, while collaborating and interacting with the mechanized hammer to produce the sound. Human guitarists can still access the fretboard without the physical interference of a mechanical system, and can play melodies and chords as well as perform bends, slides, vibrato, and other expressive techniques while the mechanical actuators excite and dampen the string with a rhythmic pattern. While leveraging the complex and fast movement of actuators, the expressivity of performing the guitar is retained. Much like how robotic musician's output can result in an inspiring real-time interaction, algorithmically generated rhythmic patterns played by mechanized portion of the RAEG can influence and surprise the performer.

2. RELATED WORKS

In the field of mechatronic instrument design, researchers have developed a number of mechanically actuated guitars, such as GuitarBot by LEMUR [4]. Most of these mechatronic guitars utilize a DC motor with plectrums for exciting the string. A few of these projects, like GuitarBot, consist of a sliding pitch shifter that manipulates pitch. Another commonality between these related instruments is that they play music automatically without any human interference. For example, GuitarBot is controlled via MIDI for performing live; performance is pre-programmed and automatic. On the other hand, previous work in robotic musicianship includes robots that perform alongside humans. Weinberg's Shimon, an anthropomorphic robot, improvises on a marimba in response to a human performer's input while the robot's output influences the performer [1]. Utilizing complex algorithms, the generated musical phrases are designed to inspire human creativity. In the middle ground between mechatronic instruments and robot musicians are robotic instruments with shared control. Much like Logan-Greene's Brainstem Cello[1], in which a mechanical system manipulates pitch or dampen strings in real time as a human performs on a cello, robotically augmented instruments allow a human performer and robotic mechanisms to share control of the sound production [1]. Gurevich and Sheffield explored this field by designing a non-traditional instrument that is mechanically augmented and establishes distributed control [2, 3]. Both instrument designers investigate shared control between human and mechanized motion within a single instrument; their behaviors are influenced by each

[1] http://zownts.com/brainstem.html

other in this dynamic system. RAEG further explores the field of shared control by incorporating robotics into an electric guitar to promote the interaction of actuators and a human which then jointly produce sounds.

Figure 1: a) Full instrument, b) Damper, c) Hammer

3. DESIGN APPROACH

The design of RAEG retains the shape and size of a conventional electric guitar with enough space next to the bridge for picking and strumming. The instrument contains six motorized hammers that hit the string while the guitarist manipulates pitch and other parameters on the fret. A major advantage of integrating mechanical components into a musical system is the ability to output musical phrases that are difficult or impossible to physically produce as a human performer. Mechanical sound production capabilities can allow musicians to explore speed, rhythm, harmonic, melodic, and timbre controls not attainable by humans alone [1]. A servo motor was chosen to support these functionalities, since unlike motorized plectrum in GuitarBot and other mechatronic guitars, it can also support dynamic and timbre manipulation. The starting position of the hammer can affect the dynamics. In order to explore timbral variations, the amount of damping can be controlled, which could affect the timbre similar to the palm mute technique. In addition, servos led to the motorized hammer design, which produces "hammering" sounds that are difficult for human to produce, especially on multiple strings simultaneously. Furthermore, larger size and movement of the hammers provide a better visual cue for the players and audiences. The prototype of this robotic guitar was designed to be simple in order to create an intuitive interaction. The software was also designed to be intuitive so that the user can input rhythmic patterns with ease. The simple design for both hardware and software is crucial for experimenting with the instrument for all users.

3.1 Hardware Design

The guitar body houses six motorized hammers and six motorized dampers, controlled by an Arduino MEGA. A servo motor is used to mechanically move a 3D printed hammer to hit the strings. In order to enhance playing speed, a small servo with low torque but high speed was chosen. Similar to GuitarBot, RAEG contains electro-mechanical dampers for each string. The dampers are implemented in the design to make sure that all the notes are pronounced cleanly, especially when playing fast. This also allows for playing short notes, which are difficult to be performed by a human, while the amount of dampening can affect the dynamic and timbre.

3.2 Software Design

Max/MSP is used to program the patterns of hammer movements. The current design of the software consists of six sequencers that allow a 16th note rhythmic patterns for each string to be inputted by users, who can easily click on the sequencers to input patterns in real time. Other parameters include BPM and activation time between the hammer and damper. In order to incorporate the crucial element of robotic musicians, users can decide to let the computer generate rhythmic patterns instead.

4. MODES OF INTERACTION

One of the main interaction modes allows the hammers to perform a rhythmic pattern while the human guitarist is fretting a bassline or chord-progression with the left hand and melody with the right hand. By leveraging the algorithmic nature of musical robots, patterns can be produced stochastically or algorithmically. Due to these varying rhythmic patterns, music with the same progression and melody sounds different each time it is performed. Also, the patterns can be generated in a way that a human would not normally play or is too complex to execute. Furthermore, advanced users can explore rhythmic patterns that are humanly impossible to execute. For example, one hammer can perform a triplet, another hammer play a quintuplet, and another hammer play a 16th note pattern. While a seasoned finger-style player could perform this with enough practice, this system can immediately output this pattern and also at a much faster speed than humanly possible. As for composing and improvising with the instrument, musicians can input a pattern, let the hammers play it, and start fretting to come up with chords and melodies. They can also decide to let the computer generate a pattern and then perform along with generated patterns. The software allows users to choose if a new algorithmic pattern will be generated every measure, every two measures, or every four measures.

5. FUTURE WORK

In order to better compose, perform, and improvise with RAEG, a custom foot-pedal will be designed. This pedal will be used to trigger various patterns, change the mode of interaction, and turn on/off the system. Furthermore, a responsive feature will be added to the instrument. Because the guitarist can choose to pick and strum the strings, the rhythm performed by the human can affect how the robotic components generate rhythm.

6. REFERENCES

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