Quadrofeelia – A New Instrument for Sliding into Notes

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ABSTRACT
This paper describes a new musical instrument inspired by the pedal-steel guitar, along with its motivations and other considerations. Creating a multi-dimensional, expressive instrument was the primary driving force. For these criteria the pedal steel guitar proved an apt model as it allows control over several instrument parameters simultaneously and continuously. The parameters we wanted control over were volume, timbre, release time and pitch.
The Quadrofeelia is played with two hands on a horizontal surface. Single notes and melodies are easily played as well as chordal accompaniment with a variety of timbres and release times enabling a range of legato and staccato notes in an intuitive manner with a new yet familiar interface.

Keywords
NIME, pedal-steel, electronic, slide, demonstration, membrane, continuous, ribbon, instrument, polyphony, lead

1. Introduction
For an instrument to be expressive, it requires several degrees of freedom for the performer. The ability to control volume, timbre and pitch in a continuous way is paramount. The goal of this project was to create an electronic instrument that matched the expressivity of the pedal-steel guitar. The pedal steel has the ability to bend individual notes of a chord while keeping the rest stable to form new chords. This method, not readily available on current electronic instruments, is featured on the Quadrofeelia.

2. RELATED WORK
The GXTar [3] interface uses a similar membrane sensor to capture continuous data from the left hand. However Quadrofeelia uses a different method for activating notes and has a second set of controllers which affect pitch. Additionally, it is oriented horizontally on a table top instead of being held like a guitar.
Many solutions have been offered that provide means of bending notes, including the pitch bend wheel and various ribbon controllers such as the Kurzweil RBN1 [2]. What isn't readily available is that which makes the pedal-steel guitar unique, the ability to bend individual notes of a chord, thus changing the chord type or voicing, as opposed to moving all the notes in unison. A previous offering geared towards keyboardists is "The Glide" [1].

3. DESIGN OVERVIEW
3.1 Modes of Expression
To achieve a comparable level of versatility in an electronic instrument continuous controllers are needed. The choice of membrane position sensors was ideal because of their continuous output range and intuitive interaction. By adding an additional force sensitive resistor (FSR) strip under the position sensor, both pressure and position can be measured simultaneously. By using position sensors for both hands to control multiple notes chords can be formed and altered in a continuous way. Lastly, additional FSRs are placed below where the palm of the hand rests to provide means to mute ringing notes to varying degrees.

2.2 Technology
The instrument uses the BeagleBoard development board and the Arduino Nano platform for I/O. The BeagleBoard is running an Ubuntu Linux distribution which enables connecting to and executing programs through an SSH connection. Installed on the Beagleboard is Pure Data (PD) which is used for interpreting the sensor data from the Arduino as well as sound synthesis. The use of the BeagleBoard for sound synthesis creates a more portable self-contained instrument. The current iteration has increased latency than with the same patch running on a more powerful computer.

4. Interaction
4.1 Control
The controls for the instrument are one long (500mm) horizontal and four short (100mm) vertical strips and a panel of four buttons. Since the instrument is modeled after a string instrument, the left hand slider is marked with vertical lines indicating musical half-steps, and dots as is typical with guitar fretboards. While the left hand has completely continuous behavior the right hand interface is partitioned off into 4

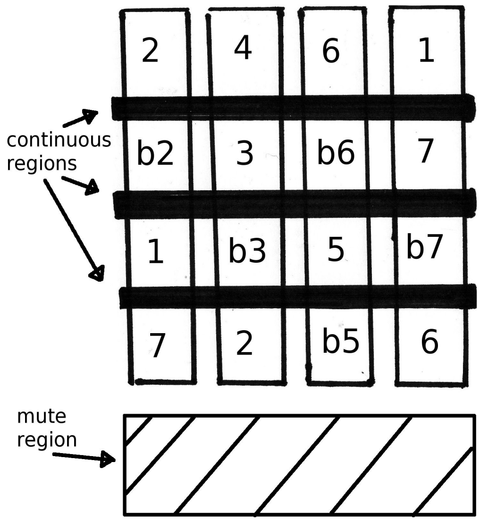

Figure 1: Right Hand interface control
Numbers indicate scale degree for initial tuning

sections per slider. Within a defined region the note does not change which makes it more forgiving. Between the static regions is a continuous region where the note will gradually change to the new region. This combination provides flexibility to be able to change notes gradually or stay locked into a set of notes.

4.2 Right Hand

Four buttons select between different key mappings, or "tunings". The mappings for the right hand were chosen to provide a simple means of playing diatonic chords. The mapping associated with the first button is shown in figure 1. The numbers indicate degree of a major scale with 1 representing the root, b3 representing a flat 3rd, etc. In this configuration the notes in a horizontal line form a minor-7 chord. Since adjacent regions for each finger position are musical half steps, changing to a major chord simply means sliding the second finger up to a new region. Below the slider regions is a "mute pad" which can be likened to muting the strings of a guitar. When a palm rests on this area the release time of the sound is shortened in proportion to the pressure applied. Thus, notes can be allowed to decay slowly or muted quickly.

Additional tunings which are changed by selecting one of the four buttons, will be familiar to other string instrument players. The second mapping creates intervals between the sliders in fourths similar to how the four lowest strings of a guitar are tuned, while the third mapping produces intervals of fifths which mirrors the intervals of the violin, viola and cello. The fourth mapping creates intervals of seconds which allows for dense chord structures to be easily played.

Simply pressing fingers down on the desired notes results in sustained notes. The surface is also conducive to swiping across a set of sliders which can be likened to strumming.

4.3 Left Hand

As with most string instruments the left hand is charged with determining the "fret" position. The common string techniques of hammer-ons and pull-offs available. Additionally, because the sensor is continuous, vibrato is easily achieved by wavering the fretting finger back and forth.

In addition to selecting the root note with the left hand, the FSR enables another mode of expression by mapping finger pressure to volume and brightness depending how hard it is pressed.

This allows the intensity of a note to be varied after it has been struck.

The interface controls are mounted on a wooden box containing the Beagle Board and Arduino chip used to synthesize the sound. Carefully placed holes obscure the wiring from the sensors. Thus, on the outside all you see is a power cable, a ¼" jack and the user controls.

4.4. SOUND DESIGN

The PD patch is divided into several sections which correspond to the various controllers. This modular approach made the patch easily scalable to the 4 note polyphony it uses. This layout could be easily scaled beyond the current 4 "strings" available. The left hand slider is mapped to a 2 octave range and each of the right hand sliders have a 4 note range with the aforementioned static and continuous regions.

4.5 Synthesis

For the sound synthesis we chose to pursue an electric guitar inspired sound which was still distinctly electronic. Each voice contains three oscillators: the first two are sawtooth waves separated by an octave and very slightly de-tuned comparable to a 12-string guitar which can sound "jangly" given the extra set of strings not being exactly in a 2:1 relationship. A third oscillator is used for FM synthesis to provide new textures at the players discretion. The sound is then filtered through a series of enveloped low-pass filters.

The pressure applied by the left hand to the fretboard maps to the FM synthesis modulation amount and filter cut-off frequencies. With a physical string the timbre changes depending where it is plucked and with how much force. Since the right hand is often occupied whilst playing Quadrofeelia, we decided to give this timbral control to the left hand.

The result is a range of timbres from mellow tones, to sharp and more complex harmonics.

5. OTHER CONSIDERATIONS

Alternative implementations considered involved a motorized wheel for the left hand which would allow scrolling continuously through a small localized range of the circle of fifths with motorized haptic feedback to assist in locking in tune. This was considered too bulky to be involved in the sliding motion of the left hand.

To improve the familiarity of this instrument to the family of pedal and non-pedal lap steel guitarists, an alternative mechanism that more closely mirrors the plucking of a string and strumming would make for an easier transition and provide additional excitation information with say an FSR tab. Maintaining the ability to bend notes may require this type of design to have a set of sensors for bending strings and another for activating notes.

Finally, extending the instrument by adding an additional 6 membrane sensors would allow for more octaves and more varied chord structures and would also match the most common pedal-steel guitar configurations which use 10 strings.

6. SUMMARY

Combining multiple membrane position sensors in a new way has allowed for a new way to bend individual notes and shape chords. Leveraging the power of the BeagleBoard and the Arduino made it possible to create a self sufficient and portable instrument.

Matching the expressivity of the pedal steel guitar in a simple interface that could be played by a beginner helped shape the final product.

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