Feedback Lap Steel : Exploring Tactile Transducers as String Actuators

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ABSTRACT
The Feedback Lap Steel is an actuated instrument that makes use of mechanical vibration of the instruments bridge to excite the strings. A custom bridge mounted directly to a tactile transducer enables the strings to be driven with any audio signal from a standard audio amplifier. The instrument can be played as a traditional lap steel guitar without any changes to playing technique as well as be used to create new sounds that blur the line between acoustic and electronic through a combination of acoustic and computer generated and controlled sounds. This introduces a new approach to string actuation using commonly available parts. This demonstration paper details the construction, uses and lessons learned in the making of the Feedback Lap Steel guitar.

Keywords
NIME, actuated instrument, augmented, lap steel

ACM Classification
H.5.5 [INFORMATION INTERFACES AND PRESENTATION] Sound and Music Computing --- Systems; C.0 [COMPUTER SYSTEM ORGANIZATION] General --- Hardware/Software Interfaces

1. INTRODUCTION
The Feedback Lap Steel is based on a standard 6-string lap steel guitar (Figure 1). It uses a tactile transducer as an actuator to put energy into the strings by physically vibrating them. The transducer is mounted in the body of the instrument with a custom bridge mounted directly to the transducer.

Figure 1: Playing the Feedback Lap Steel

The transducer is driven by a standard audio amplifier allowing any audio signal to easily be used to drive the strings. By using the output of the instrument as a sound source that is amplified and fed back into the bridge actuator, a feedback loop is created that is controlled and manipulated with filtering, delays and other effects. The Feedback Lap Steel demonstrates the potential of using tactile transducers as a string actuation technique.

2. RELATED WORK
The idea of self sustained oscillation was brought to a handheld device with the EBow[1]. Similar devices that mount to a guitar include the Sustainiac[2] and Fernandez Sustainer[3]. In 2008 Moog Music introduced a guitar with actuation technology built into the instrument[4], they have since released several versions including a lap steel guitar. These instruments feature a sustain mode as well as a "mute" mode that uses out of phase signals to halt the motion of the strings.
Other explorations in actuated instruments and related control theory include the Feedback Resonance Guitar [3], the Electromagnetically Prepared Piano [4], the Magnetic Resonator Piano [6] and the Electromagnetically Sustained Rhodes Piano [8]. These instruments are able to sustain notes indefinitely as well as induce sound from silence, creating swells not otherwise possible with plucked or struck stringed instruments.
The Overtone Fiddle [7] uses a tactile transducer to vibrate the body of the instrument, essentially using the body as a speaker but not inducing string vibration.
Quadrofeelia is an example of digital music instrument inspired by a lap steel guitar. [5]

3. INSTRUMENT DESIGN
The Feedback Lap Steel was mostly built by hand from materials available from the hardware store. It was based on a "Do-it-Yourself" lap steel guitar design available online[5].

3.1 Building the lap steel
The body of the guitar was cut from a piece of 2"x6" redwood decking material. The bridge and saddle hardware were replicas made for a Les Paul Jr. electric guitar. The nut of the instrument and electronics panel on the front were made by cutting and bending metal plates found at the hardware store. The fretboard of the instrument was cut from ¼" plywood.

3.2 Sound Actuator
The sound actuation is created with a tactile transducer known as the "Puck"[15]. This device is sold as a "bass shaker" intended to be used in home theater, gaming and auto sound applications. These devices are basically speakers without the air moving speaker cone. By rigidly attaching them to surfaces they essentially turn the surfaces into speakers or shakers. The actuator is powered by a 40 Watt class-T digital amplifier.

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[1] http://www.ebow.com/
[2] http://www.sustainiac.com/
[3] http://www.fernandesguitars.com/sustainer/sustainer.html
[4] http://www.moogmusic.com/products/Moog-Guitars
[5] http://www.buildyourguitar.com/resources/lapsteel/

Figure 2: Feedback Lap Steel Bridge mounted to the Puck tactile transducer

The bridge was laser cut out of 1/2" acrylic to mate with the top of the transducer (figure 2). The top of the bridge was scored with six cuts by the laser cutter to accommodate the strings.

3.3 External Connections

The output of the instrument is routed either to a laptop or a Raspberry Pi running the Satellite CCRMA to create a standalone system[1][2].The output audio signal from the computer or embedded processor is then routed to the audio amplifier that sends a powered signal to the transducer via an RCA cable.

4. PLAYING THE INSTRUMENT

Lap Steels are played with a steel bar that slides on the strings. The right hand is used to pick the strings, or in the case of the Feedback Lap Steel may be left free to control other effects. It is played with two volume pedals, one for the output and one to control the input signal.

4.1 Software and Control

A typical feedback control patch will take in the signal from the guitar and perform some basic processing before sending it back out to the actuator. Without processing the feedback produces high order (screeching!) harmonics. Various techniques of controlling the feedback have been explored including filtering, pitch shifting and delays. The implementation of a low pass filter allows control over the harmonics excited in the strings. Pitch shifting produces unique results. Shifting down an octave down, the upper harmonics remain stable. By doing micro pitch shifts slightly off the original output from the instrument beating effects are achieved that create a dense yet controllable texture not available with a traditional instrument.

The feedback system can be controlled in a variety of ways, either by changing parameters or calling up presets with a computer mouse and keyboard, or better through a series of dedicated buttons and variable controls such as knobs and sliders. Both approaches have been used but the control interface is still very much in development.

4.2 More Possibilities

By routing live audio from another instrument or voice through the Feedback Lap Steel, it produces sympathetic vibrations with the audio source. When this is done the player can highlight different harmonics by changing the effective tuning by moving the steel bar. By using percussive sounds (from a drum machine for instance) rhythms can be injected into the strings.

5. CHALLENGES AND LESSONS

An attempt was made to acutate an existing guitar by mouting the transducer to the back of the guitar directly behind the bridge. This configuration did enable sustain but did so inconsistently and only at very high volumes.

The use of audio programming languages to process the audio produces significant latency (for a feedback control system) and can be somewhat unpredictable.

Another limitation of this approach is the use of a single pickup and single transducer limits the amount of control available since all six strings in this case combine to create one signal. Similarly all six strings are physically coupled to the same actuator at the bridge.

6. FUTURE WORK

Better characterization of the feedback system will enable more robust applications for controlling the behaviors. A current amplifier as opposed to the inexpensive audio amplifier used would provide better control of phase. Experimental development of a metal bridge is underway to experiment with different materials. This will include various types of aluminum and steel as an alternative to the current acrylic bridge. The harder materials are expected to better transfer energy to the strings as well as be more durable.

7. SUMMARY

This paper introduced the concept and design of the Feedback Lap Steel. It participates and contributes to the growing field of actuated musical instruments that are "co-manipulated" by a human performer and an electromechanical system. It is an actuated lap steel guitar featuring a tactile transducer actuator to inject energy into the strings. It introduces the idea of using a bridge mounted directly to a tactile transducer as a means of mechanically inducing vibrations in a stringed instrument. Feedback occurs by sending the instruments output back into the actuator while control is achieved through various processing techniques. Additional explorations with a variety of audio input used in conjunction with this instrument are described, with many still to be explored.

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