The Whammy Bar as a Digital Effect Controller

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ABSTRACT

In this paper we present a novel digital effects controller for electric guitar based upon the whammy bar as a user interface. The goal with the project is to give guitarists a way to interact with dynamic effects control that feels familiar to their instrument and playing style.

A 3D-printed prototype has been made. It replaces the whammy bar of a traditional Fender vibrato system with a sensor-equipped whammy bar. The functionality of the present prototype includes separate readings of force applied towards and from the guitar body, as well as an end knob for variable control. Further functionality includes a hinged system allowing for digital effect control either with or without the mechanical manipulation of string tension.

By incorporating digital sensors to the idiomatic whammy bar interface, one would potentially bring guitarists a high level of control intimacy with the device, and thus lead to a closer interaction with effects.

Author Keywords

NIME, augmented instrument, digital effects controller, electric guitar, whammy bar, vibrato arm, human computer interaction, embodiment

CCS Concepts

•Applied computing → Sound and music computing; •Human-centered computing → Haptic devices; •Hardware → *Haptic devices;*

1. INTRODUCTION

The primary aim for this project was to focus on the user experience of effect control for guitarists, and coming up with design solutions that are tailor-made for this particular instrument.

The whammy bar became the interface of choice due to several factors concerning control intimacy, [19] embodiment, [7] multimodal feedback, and compliance with visual guitar aesthetics, as well as a sense of familiarity for guitarists regarding gestural control. The impression is that an incorporation of digital sensors to a well known interface, would create a high level of control intimacy with the device, and thus lead to an embodied interaction with effects. Using the whammy bar as an interface also allows effects to be controlled right at the onset/attack of the excitation of the string, as well as bring a strong multimodal feedback (haptic, visual, and aural) to the player.

Using a whammy bar for expressive effect control provides an interface that exploits the fine motoric capabilities of the hands, which are the main tools for musicians interacting with their instrument. This puts timbral manipulation at the forefront as a musical parameter, and due to the design of the whammy bar, it does not create a sizable compromise to normal guitar playing, as it allows for usage along with regular right hand guitar techniques. There is also the important factor of transparency, as in the degree of experienced match between the input and output of a device.[9] Since the interface is designed as a general digital controller, the aural feedback from the system is inevitably determined by the player rather than the designer, but due to the arguably strong haptic and visual feedback from the whammy bar interface, a certain level of transparency is guaranteed.

2. CONTEXT

In this section we aim to show the project in a broader context to clarify the motivation behind our research. We will give a brief introduction to instrument augmentation, effect control, and the whammy bar system, as well as some insight into 3D-printing technology, which was the chosen production method for the prototype.

2.1 Augmented instruments

This research project is part of a larger augmented instrument paradigm, where developers share the goal of finding new ways for the musician to interact with their instrument by transcending current design limitations.

There have been numerous research projects regarding augmentation of many different instruments, like [21, 3, 17, 26, 25, 28], and there have also been quite a few guitar-oriented augmentation projects, and in specific within the NIME community in recent years. [16, 6, 23, 5, 2, 11, 10]

Other equally important and relevant research to this project, is the vast amount of general theory on product design and human-computer interaction, (e.g. [20, 1, 13]) and more specifically theory relating to how instruments and controllers are to be designed for the highest musical value. [19, 8, 18, 12, 24]

2.2 Effect control for guitar

The possibilities for what guitarists can control have advanced considerably in recent years, both with hardware (e.g. Kemper Profiler[1]), and software (e.g. Positive Grid BIAS FX[2]), but the fashion in which one controls these numerous musical parameters available, have not seen much

[1] www.kemper-amps.com
[2] www.positivegrid.com/bias-fx/

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development among conventional guitar players. The floor based controllers still reign the market – both for discrete effect changes, and expressive control (expression pedals), and this is probably due to that both hands are occupied with playing in most conventional guitar playing techniques.

In recent years we have seen a growth of innovative commercial effect controllers being made, both add-on controllers (Guitar Wing[3], Aalberg AERO[4], Source Audio Hot Hand[5], REVPAD[6], and ACPAD[7]), as well as guitars with built in sensors like the Sensus Smart Guitar[8]. This development may be due to technological advances like Bluetooth LE and more compact microprocessors, which have made digital controllers more practically positioned on the guitar itself, but it also suggests that there is great interest in finding new user interfaces for guitarists to interact with effects.

When using the feet for timbral manipulation, it arguably puts effect control at the "periphery of the playing technique".[16] The very concept of using the feet for gestural control, points more towards a universal design, meaning it is equally accustomed to other hand-played instruments.[14] From a semantic perspective, one could argue that a guitarist who uses floor based controllers is playing two instruments at once, as neither the physical construction nor the gestural control of the pedals have any relation to the definition of a guitar.

2.3 The Whammy Bar

The mechanical whammy bar is an example of an augmentation of the guitar that has become widely embraced. Since its introduction in the 1950‘s, the whammy bar has become a standard peripheral on many guitars – the most famous being the Fender Stratocaster. Its success can be boiled down to two main factors: Characteristic aural results, and a user interface that guitarists find intuitive, enjoyable, and easy to integrate with their playing style.

As far as we know, the whammy bar or a similar kind of user interface, has yet to be used as an interface for general effect control for guitar. There are however related products, like the electronic whammy bar on the Ibanez IMG2010[9], and the Virtual Jeff electronic pitch controller[10]. This research project differs in that it combines the mechanical whammy bar system with digital control of any musical parameter, as well as expanding the performance gesture possibilities of the whammy bar user interface.

2.4 3D-printed hardware

3D-printing, or rapid prototyping, was used to make a functional prototype of the whammy bar effect controller, and the choice was based on the several new possibilities this technology yields. Rapid prototyping allows for a lean development model, meaning that a product can be refined and improved through several iterations based on user feedback.[22] Making smaller batches of a product is far more convenient compared to traditional production processes, as one is not dependent on costly injection molds. It also allows for greater flexibility in product customization based on individual user needs.[4] In addition, 3D-printing makes global cooperation more convenient by way of sharing 3D-models, PCB designs and simulation data, as well as 3D-printing experiences and know-how, all which could favourably aid the development process of the whammy bar digital effect controller.

3. THE DESIGN OF THE CONTROLLER

In this section we present the current 3D-printed prototype in greater detail – how it functions and the intentions behind the different design choices. We also give brief suggestions for possible effect mappings.

3.1 Functionality

The prototype is designed to replace the vibrato arm on a traditional Fender vibrato system with a sensor equipped arm. The functionality of the present prototype is presented in this chapter. See figure 1 for a depiction of the current prototype, and please visit the referenced web link for a video demonstration of the prototype.[15]

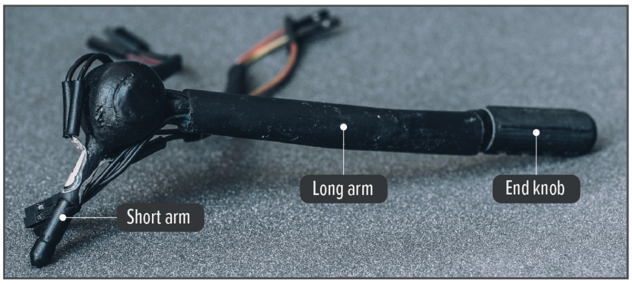

Figure 1: The current prototype of the controller with explaining terms.

3.1.1 Two modes

The controller includes a hinged system allowing for digital effect control either with or without the mechanical manipulation. This was seen as an important design choice, as being forced to combine the mechanical and digital effects would limit the player‘s sonic possibilities considerably. In both modes, a separate reading of data towards and from the guitar body is possible, allowing for different effect settings in either direction.

In the *locked* mode, the angle between the longer part of the bar and the shorter end (placed in the bridge hole) is fixed. In this mode the guitarist is free to either use the whammy bar purely for its mechanical effect, or with an added digital effect. *Example effect mappings:* The mechanical pitch shifting can be made more extreme by adding a digital pitch effect on top.

Using the *unlocked* mode means that the mechanical system is not affected by the player‘s use of the whammy bar, thus the interface becomes a purely digital effect controller. *Example effect mappings:* Sustain or swell.

An important aspect of the design in the unlocked mode was the implementation of a spring system, as this would allow the player to feel a type of haptic feedback similar to a mechanical whammy bar system (see figure 2 and 4).

3.1.2 End knob

The prototype is equipped with an end knob that brings variable digital control through a twisting motion. This gives the unit an extra gestural control input compared to the mechanical whammy bar. The choice of this added functionality was based around two main factors:

- Having the knob in close proximity to both the right hand and the whammy bar itself, maintains a low latency between intention and action.

[3]www.lividinstruments.com/products/guitar-wing/
[4]www.aalbergaudio.com
[5]www.sourceaudio.net/hot-hand.html
[6]www.gtcsound.com/
[7]www.acpad.com/
[8]www.mindmusiclabs.com/
[9]www.joness.com/gr300/img2010.htm
[10]www.fomofx.com/

- Many whammy bars already come with a tip, thus adding one for digital control would not breach any established guitar aesthetics.

Haptic feedback was an important criterion for the user interface as a whole, and since a rotary switch has a more limited haptic response compared to the whammy bar with springs, a tactile surface was designed for the guitarist to maintain orientation without the need for a visual cue (see figure 2). *Example effect mapping:* Change of effect preset.

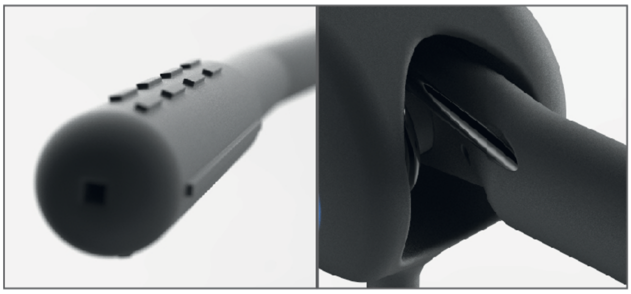

Figure 2: *Illustration.* Left: The end knob's tactile surface. Right: Close up of the torsion spring.

3.2 Technical setup

As the main point of focus for this project was on user experience and not on the technical setup, we did not experiment with innovative sensor technology, nor was this seen as necessary to digitally measure the data from the guitarist's playing. All that was used were two potentiometers and two force sensitive resistors. To accommodate the small size of the whammy bar, the sensors had to be as small as possible, while at the same time yielding a satisfactory result in data reading.

The two force sensitive resistors were placed on either side of the short end of the bar to measure the applied force from the guitarist's hand onto the vibrato arm (in locked mode). Two sensors were needed in order to register force from either upwards or downwards movement of the bar.

In the unlocked mode, a potentiometer takes over the reading of data. The potentiometer is connected to an axle, which again connects the two main parts of the arm (short and long), and this results in a data reading that is proportional to the up and down movements of the long arm.

A similar potentiometer is used to read movement of the end knob. The present potentiometer has no indents, which arguably makes it more suited for expressive control rather than discrete changes (e.g. change of effect preset).

An Arduino Uno was used to connect the sensors to a computer running Ableton Live and the Arduino Max4Live device from the Connection Kit bundle. This allowed for an easy, yet effective and functional, setup (See figure 3).

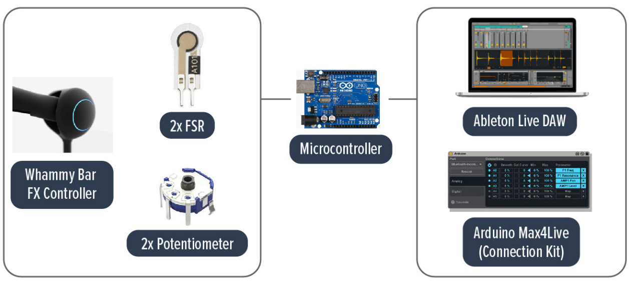

Figure 3: Overview of the technical setup

Figure 4: Exploded views of the 3D-model.

4. FUTURE WORK

Future work will focus on improving different aspects of the prototype to make it ready for user testing. First step is to reprint the prototype with a more durable and stiff material (e.g. carbon fiber). Other improvements include a smaller electronic circuit, wireless data transmission, a new design for efficient switching between locked and unlocked mode, as well as better haptic feedback in the unlocked mode. The idea for the latter is to install a spring system with calibration of tension in accordance with the tension in the mechanical vibrato system. Another goal is to make the design adaptable to other common vibrato systems, as well as to be used purely as a digital controller add-on for guitars without a mechanical vibrato system.

4.0.1 Expanded functionality

During the research period, it became apparent that the whammy bar as a user interface has an innate potential that is not fully exploited in the purely mechanical systems of today. By implementing sensor technology, this potential can be brought to life. The current prototype hints at this with the end knob control, as well as separate data reading when pushing the vibrato arm towards and away from the guitar body. Here we present two additional performance gestures that have been found promising for effect control:

- **Linear motion along the length of the whammy bar**. A variable effect control based on where on the bar the finger touches. *Example effect mappings:* A high pass filter or overdrive to complement and enhance the change in timbre when plucking the strings at different distances from the bridge.
- **Circular motion of the whammy bar around its pivot point in the bridge hole**. With a digital reading of this motion, it would allow the guitarist to use the whammy bar for effect control while performing techniques like strumming, as the bar would follow along the same axis as the gestural movement of the hand. *Example effect mapping:* The circular motion can be used to control volume swell. This effect could also work favourably

in conjuction with the mechanical vibrato.

For a demonstration of these two possible features, see referenced video at *1:50*. [15]

5. CONCLUSION

In this research project we have made a functional prototype of a digital effect controller based on the vibrato arm as a user interface. The main goal was to design an expressive digital effect controller that feels accustomed to guitarist's conventional playing styles, and thus bringing an uninterrupted interaction between timbral control and other musical parameters. Through the fine motoric capabilities of the hands, the interface also allows for an advanced level of effect control, and thus complies with the ideal of a "low 'entry fee' with no ceiling on virtuosity".[27]

With further work, we aim to make a prototype that is suitable for more widespread user testing among guitarists, which certainly would benefit the development process of the whammy bar digital effect controller.

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