The Ghost: an open-source, user programmable MIDI performance controller

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ABSTRACT

The Ghost has been developed to create a merger between the standard MIDI keyboard controller, MIDI/digital guitars and alternative desktop controllers. Using a custom software editor, The Ghost's controls can be mapped to suit the users performative needs. The interface takes its interaction and gestural cues from the guitar but it is not a MIDI guitar. The Ghost's hardware, firmware and software will be open sourced with the hopes of creating a community of users that are invested in creating music with controller.

Keywords

Controller, MIDI, Live Performance, Programmable, Open-Source

1. INTRODUCTION

The creation of The Ghost came from an interest in the sound generating/sculpting abilities of synthesizers, my background as a guitar player as well as from the desire to control Digital Audio Workstations with a performance controller that allows for mobility and gestural control. Many of the innovative commercial controllers released in the past few years have succeeded in moving the performance out of the laptop. Unfortunately, most have not moved much further than the desk space next to the laptop. Borrowing the form factor of the guitar, The Ghost presents itself in a familiar yet new package. Most of the familiar gestures associated with the guitar translate to The Ghost. Strumming and picking notes as well as scalar runs up and down the neck are adapted to the new interface. With that said, The Ghost is not intended to be a guitar or a digital guitar. There are many MIDI guitar systems and digital guitars available today but these are designed for guitar players using a 1 to 1 recreation of the guitar interface. The intended users of The Ghost are not only guitars players but also keyboard players, computer musicians and people that are new to playing musical

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Figure 1. The Ghost MKII

instruments. As I will explain further in the paper, The Ghost interface can be made as easy or complicated, as the user requires.

2. SYSTEM

A basic overview of the system in use can be summed up like this: the user chooses presets or creates their own control mappings in the software editor and loads them (as .txt files) onto an SD card. The SD card is inserted into The Ghost and the mappings are read and parsed by the microcontroller. Using the onboard rotary encoder (data knob) with "press to select" function and the LCD screen, the user can select a mapping or "patch" and begin playing. There are a few modes of play that can be accessed within one patch so that mappings can be changed during a performance.

Depending on the mode of operation, The Ghost can act as a melodic lead or harmonic rhythm instrument, sequence percussion or trigger samples. The user interface consists of 48 LED pushbutton switches (arranged in three rows of 16 along the neck), eight resistive touch sensitive switches, four rotary potentiometers, a SoftPot linear potentiometer, a "whammy bar" (spring loaded control stick), four "mode" selection slide switches and a two axis accelerometer. How The Ghost is played depends on how the controls are mapped and what modes are active. The three main modes are Chord, Note and Drum.

In Chord mode, the user has mapped chords to 36 or 48 buttons along the neck. The system is open but as I play The Ghost (see Figure 2), the top row of buttons are mapped to Major chords and ascend in fifths from C Major. The second row of buttons are set as the relative Minor chord of the Major chord in the first row. The third row of buttons act as "shift" keys not unlike on a QWERTY keyboard. By pressing a Major or Minor chord button and one or multiple shift keys, additional chords can be played including Seventh, diminished, and augmented chords. A number of other chords and voicings can be programmed from the software editor. Pressing multiple chord buttons at once can create polychords, something not easily achievable on a stringed guitar or conventional keyboard. While simply pressing a single or combination of buttons on the neck can produce sound, the deeper interaction comes from the use of the touch plate located on the body of The Ghost. By selecting the use of the touch plate, the user can break up the chord into individual notes which can be laid out in a number of different ways. The plate can arpeggiate the chord in a root, third, fifth fashion, play a scale in the key of that chord or even play notes reflecting those that would be played if The Ghost were a guitar. The mapping of the plate function, like the functions of the buttons along the neck, can be edited in software. The upper 12 buttons can be mapped to a number of things but one idea is to have them laid out to represent a chromatic scale so that scales and lead parts can be played with accidentals while in Chord mode as shown in Figure 2.

The second main mode of play is the Note mode. This mode allows the user to have each button represent a MIDI note as opposed to a chord. This mode is suited for melodic or lead playing as opposed the the harmonic nature of the Chord mode. The user can map the 48 buttons to any notes they choose allowing for a completely custom performance interface. The mapping can be based on music

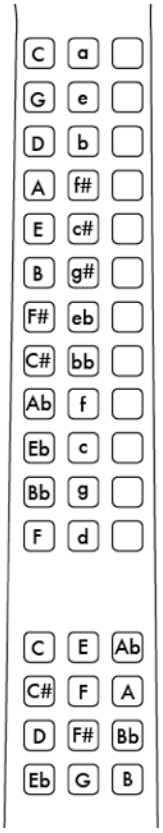

Figure 2. Example Chord and Note Mapping

theory principles like scales or can be set to mimic other instrument layouts. By mapping MIDI notes to functions in the user's DAW, the buttons can act as drum or sample triggers, clip launchers in Ableton Live, control MAX/MSP or any other MIDI controlled function within the user's software. The aforementioned mode switches can select whether or not the 48 buttons access chords or notes, whether the chords/notes are played automatically or triggered from the touch plate, change the mapping of the touch plate from two preselected options or turn the drum programming mode on.

In the Drum mode, the 48 buttons along the neck are used to create percussive patterns that can be edited and manipulated in real time. Programming the patterns is similar to the programming of a x0x style drum machine. On The Ghost, the top row of buttons display the pattern for the selected MIDI note or drum hit. The LEDs cycle through along the 16 steps of the middle row of buttons. The active MIDI note/drum hit is selected by the third row of buttons. The MIDI note numbers are selected in the software editor and 16 can be stored in one patch. By selecting a MIDI note/ drum hit, the hits can be placed along the 16 beat timeline. Pressing a button illuminates it, signify that it is active and will be sending a MIDI note on that step. Pressing the button again will clear that step of the MIDI note. The middle row of buttons also act like a scrub selector for the step timeline. Pressing any one of the 16 buttons in the middle row will cause the "play head" of the drum pattern to skip to that step. For example, if the sequence is running and is currently at

step 10, the user can press the fourth button and the pattern will jump to step four. This way, the user can dynamically play the sequenced pattern and change its play order on the fly adding another interaction to drum sequencing. The tempo of the pattern playback is controlled via the rotary encoder.

Along with these modes of play, The Ghost is equipped with seven continuous controllers for the user to manipulate during a performance. Four rotary potentiometers can be mapped to Continuos Controller messages in the user's DAW and control things such as volume, frequency cutoff, envelope parameters etc. The three other performative controls are the SoftPot linear potentiometer, "whammy bar" and two axis accelerometer. These controls can be freely mapped but here are some of the uses I envision. The mod strip can as a modulation source as on a standard MIDI keyboard controller or can control other parameters such as filter cutoff or resonance and pitch shifting. One interesting mapping would be to set the SoftPot to control the pitch of a synthesizer as one would do with a ribbon controller. The whammy bar is spring loaded and can act as a pitch bend control, or more interestingly, a volume control. In this usage, a user could trigger a note with their left hand and then smoothly swell the volume up to create a soft attack and decay like a violin or theremin. The 2 axis accelerometer is interesting because it allows for using gestures normally associated with the electric guitar but in a different manner and with different results. By tilting The Ghost vertical, with the headstock pointing increasingly upward, the user can change the octave or register in which they are playing. The more vertical the instrument becomes, the higher the octave it is playing in. The other axis is also interesting in that when the body is pulled upward, making it perpendicular to the ground, a parameter will be changed. Perhaps for example the feedback or delay time of a digital delay effect.

With all of these controls, the MIDI channel can be freely assigned in the software editor so that individual controls can control several digital instruments. To add to the visual presence of the Ghost, the headstock contains eight white LEDs that turn on when the corresponding touch plate is activated. Sweeping a hand across the touch plate creates a shimmer of light which creates a visually pleasing effect for the audience.

3. HARDWARE

The Ghost's hardware is comprised of three key circuit systems. They are the button boards, touch plate and master controller. The design of the hardware has been made intentionally modular. The idea behind this is that electronics can be rehoused in the future to create new interfaces based on the same electronics. Figure 3 shows the button boards assembled and in place next to the neck. Each board contains an ATmega168 microcontroller that is programmed from the Arduino[1] IDE. Arduino was chosen because of its large user community, ease of use and commitment to open source. Each button board runs the same program and uses row column scanning to read button presses and light up LEDs. Its address is selected via a four position DIP switch. The input information is sent to the master controller via i2c protocol. The LEDs can be addressed individually from the master controller. As an aside, the result of having a

Figure 3. LED button boards

microcontroller on each button pad is that each 3x4 unit is conceivably its own instrument. By writing MIDI out commands to the firmware, each button pad can send MIDI data directly to a sound generator. Therefore, if the button pads are used outside of The Ghost controller, any number of new interfaces can be derived from this platform.

The master controller, as seen in Figure 4 is run by an ATmega1280 and is also programmed via the Arduino IDE. The master controller handles all of the control data, SD card input, MIDI output as well as control circuitry for the touch plate. As previously mentioned, the touch plate consists of eight switches. Each switch is made up of three copper traces that are arranged in an interleaved zipper configuration where one trace carries a ground signal and the other two are trigger inputs feeding the control circuit. When a finger bridges the two signals to ground, a pulse is sent to the control circuit. Firmware is currently being developed

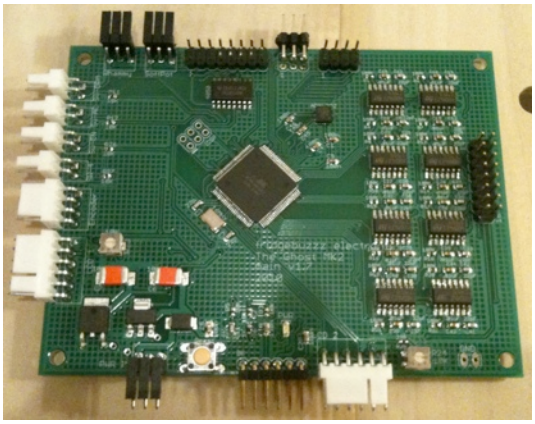

Figure 4. Master Control Board

where the master controller compares the timing of the two input triggers and can derive velocity data from it. The touch control circuit is created around a 556 timer in monostable mode.

Power distribution was a considered aspect of the hardware design. USB Bus-powering The Ghost was considered but ultimately, a custom MIDI cable and breakout box were created to be able to meet any current draw from future hardware additions and allow for both Data and Power lines to be run on single cable. In addition, there is a DC power input allowing for a standard MIDI cable to be used in the event it is needed

[1]Arduino. http://www.arduino.cc

For the construction, The Ghost was built based on techniques and materials associated with electric guitars. Solid wood was cut to shape and the neck and body has been chambered to accommodate the electronics. Both hand cutting and laser cutting methods were used in the design and fabrication of The Ghost. The neck is a bolt-on style and the back plate is clear acrylic so that the electronics can be seen.

4. SOFTWARE

The Ghost software editor is written in the open source Processing[1] environment. The editor is a Processing applet that writes text files to the computer it is running on. These text files become the presets that are loaded onto an SD card and inserted into The Ghost. Different user maps can be accessed on board The Ghost via the rotary encoder and LCD screen. Figure 5 shows the GUI for the Ghost Editor. Each button pad is represented by a square and can be selected and made active. Once a button is active, it can have attributes associated to it. There are four tabs at the top of the screen. They are: Chord, Note, CC, and Channel. The Chord tab provides a drop down menu for the user to select a chord to

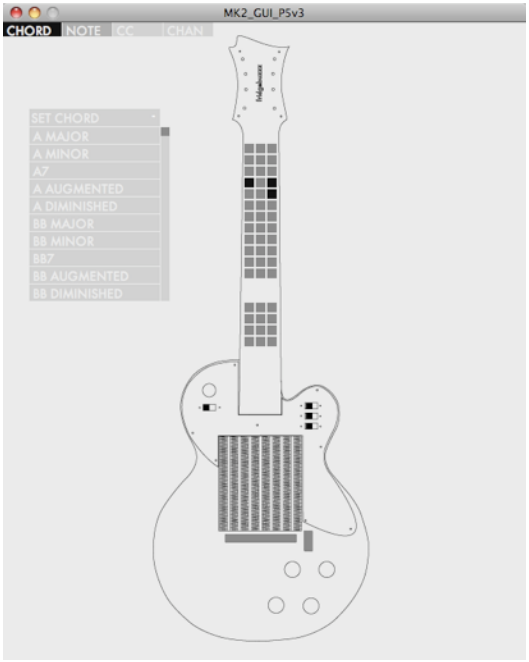

Figure 5. Ghost Editor Software

be associated with that button. Likewise, using the Note, CC and Channel tabs, MIDI notes, CC messages and MIDI channel can be attributed to a button or a combination of buttons. The CC controls can only be assigned CC messages and MIDI channels.

Creating unique mappings is one of the exciting aspects of The Ghost. Each individual player can lay the controls out as best suits them. Different mappings or "patches" can be stored in the controller to use within one performance. As mentioned earlier, The Ghost can be as easy or challenging to play as the user wants. For a simple example, the user could create a "patch" that has the chord progression for a particular song arranged down the neck. Different sections of the song i.e. verse, chorus, bridge, could be set along different rows of the neck. The user would only have to press the appropriate button while moving their hand down the neck while strumming the touch plate to play a song. For this reason The Ghost could be a very accessible first instrument for a new musician.

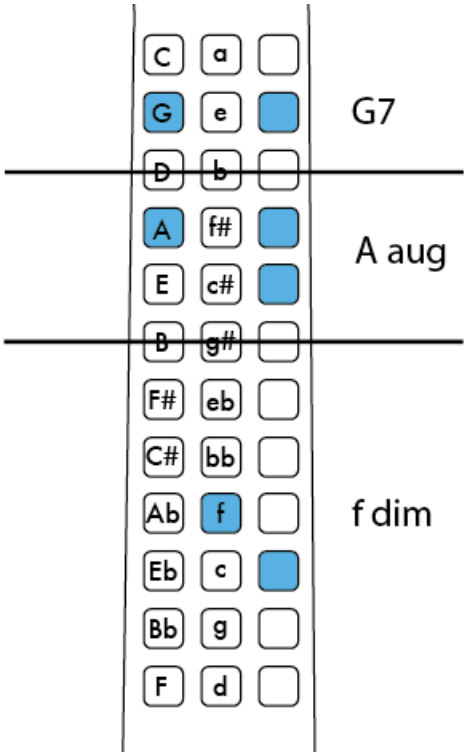

Figure 6. Button combinations create additional chord qualities

On the other end of the spectrum, complex patches can be created that involve the use of many buttons held down at once to create different chord qualities. In Figure 6 you can see a number of different chords that can be made from a few button presses within a given mapping. By using the shift keys directly below and adjacent to the chord that is being played, different chord qualities can be achieved.

5. OPEN SOURCE

One of the hopes for The Ghost is that users will share their patches and come up with creative new mappings as well as expressive new ways of using the controls. Inspired by the monome, this idea of building a community around an instrument is what lead to the decision of making it open source. By opening the firmware, hardware and software, users can make what they want of The Ghost platform and create use cases that I have not thought of. This is also what will set The Ghost apart from other MIDI controllers on the market. By using the Arduino platform, The Ghost is accessible to a wide audience of makers, hackers, and intrepid musicians.

As previously mentioned, The Ghost's electronics have been modularly designed. The button boards come in

[1]Processing. http://www.processing.org

arrangements of three buttons by four buttons. Since each board has it's own microcontroller, it can be programmed to be a controller in itself. A simple change in code and the addition of a MIDI DIN socket, the button board is a 12 button controller.

6. EXPERIENCE

In use, playing The Ghost is fairly straightforward. Technique can be developed for more advanced playing styles but ultimately, since there are no moving parts like strings, a user can begin playing with very little practice. For me, a guitar player, it felt very natural to play and in my observations during user testing, other players took to the concept very quickly. Even if a user has not played a guitar before, the two handed playing technique is known and established and even commonly experienced through music games such as Guitar Hero and Rock Band.

After some time playing The Ghost, I have realized that the physical feedback provided by the touch plates is not as good as it could be. One of the great things about playing the touch plate is that one can effortlessly swipe their hand across all eight switches and strum notes with ease. Where this system becomes less than ideal is when a player wants to play specific notes individually. This can be accomplished but in my experience, the user needs to look down and visually see the touch plates in order to strike the correct one. I am still searching for a way to provide tactile feedback so that the user can feel which switch they are currently touching. This will allow for more accurate picking and the freedom to disengage ones eyes from the touch plates while playing.

Although there is no foot controller in The Ghost system, general MIDI controllers can be used to enhance the playing experience. In my own performances, I have used a Behringer FCB1010 to change sound patches on the fly as well as trigger samples and send MIDI CC messages with foot treadles. With two foot treadles, I am able to adjust the volume and pitch of the synthesizer adding new dynamic control.

7. ALTERNATIVES

During the development of The Ghost I have looked into many of the commercially available MIDI and digital guitars. Instruments such as the Roland V-Guitar System, the Yamaha EZ-AG, the Misa Digital guitar, and Starr Labs Ztar series are similar in appearance but have different functionality. As mentioned earlier in the paper, I do not consider The Ghost to be a guitar at all but a programmable MIDI controller in the form of a guitar. The Ghost takes the form of the guitar for its interaction and gestures as well as its familiarity. Most users who have tested The Ghost have instinctively known how to begin playing it. The Ghost could easily be a rectangularly shaped desktop unit or long and narrow like the Chapman Stick. The reason for adopting the guitar shape was to make The Ghost more intuitive and accepted among users unfamiliar with alternative music controllers. In addition, as a guitar player myself, it felt natural to leverage my experience in guitar playing and building to create a new interface.

What the aforementioned instruments have that make them true guitars, digital or otherwise are their control layouts. Each of these instruments have a 1:1 recreation of the guitar interface, meaning 20+ columns or "frets" of buttons multiplied by six rows of "strings". They also all, with the exception of the Misa, have physical strings as a control device. By simplifying and resizing the buttons along the neck of The Ghost, the user is not forced to think as if they were playing a guitar. In addition, the touch switches, when held, can provide infinite sustain like a keyboard instrument. On top of these points, The Ghost is an open platform designed to be revised and refined by the user. With access to software, firmware and hardware, the user is free to alter the functionality of the instrument however they see fit. The aforementioned guitar controllers operate within closed systems that can only be partially altered by the user and require previous knowledge and skill on the guitar to play them.

The controller that I see as the most similar to The Ghost is the Eigenharp from Eigenlabs. Both instruments leverage classical instrument styles and provide open and customizable platforms for musical expression. The Eigenharp is without a doubt a far more complex and precise instrument but that comes at a price not suited for everyday musicians. What The Ghost lacks in depth of control, it makes up for in mass appeal and accessibility. While I do not have a price associated with a commercial version of The Ghost, it would fall significantly under $1,000 USD, making it within reach to a larger population of musicians.

8. FUTURE

The Ghost MK2 will be presented on May 5 as my thesis project for the completion of my masters degree at the Interactive Telecommunications Program at New York University. I am currently gauging interest in The Ghost as a commercial controller and will be looking into manufacturing possibilities in the Summer of 2010. Further information including schematics and source code will be available at www.fridgebuzzz.com/synth/TheGhost.html.

9. ACKNOWLEDGMENTS

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