Electronically Modified French Horn

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ABSTRACT
This project aims to create an electronically augmented French horn. I have created a prototype for electronic augmentations that can be mounted onto the French horn and used in synchronisation with the regular function of the instrument. My design focuses on intuitive control for the horn player and unobtrusive sensor placement on the instrument. It is also vital that the modifications to the instrument are non-destructive to the instrument and removable.

Keywords
French Horn, MIDI Controller, Teensyduino, Electronic Augmentation, Sensors

1.INTRODUCTION
Electronically augmenting an instrument is a familiar concept that has been repeated and explored by many other research projects. However the French horn is an instrument rarely brought into a sonically and electronically experimental scope. The ergonomics of playing the French horn are unique and demanding, requiring both hands to hold and play the instrument, as well as the mouth. This high level of control for the base instrument leaves very limited movement available to control the electronic augmentations added to the instrument. My aim in my design is for the horn player to be able to control MIDI effects from the horn while still playing with correct technique and ease. To do this I have added buttons to the handgrip around the keys, and pressure sensitive resistors inside the bell opposite where the horn player places their hand. This project will be able to be used in performance scenarios, as well as being a tool for contemporary composers looking to work with electronics.

A big part of my motivation for doing this work is that I'm a horn player myself. Knowing the ergonomics of playing the horn, as well as what can be added to the instrument without damaging it or effecting the sound is key to creating usable augmentations. French horns are typically confined to the classical world, and have rarely ventured into jazz, pop, or more experimental electronic music. It is my hope that my research will prompt further experiments into adapting the horn with electronics.

2.RELATED WORKS
When looking for inspiration, I focused on other designs for hyperinstruments and electric acoustic instruments. My requirements for my own design are intuitive control for the player, unobtrusive sensor placement, and non-destructive mounting of all components. The first project I looked at was Hans Leeuw's *Electrumpet*. Leeuw's intention was to have electronic components that were intuitive and could be controlled similar to how the trumpet was controlled. The controls he used for the electronics were electronic valves, pressure sensors, action buttons, slide buttons, and a ribbon controller.[1] The concept of this design was alike to having an effects board mounted to the instrument, which is something I have emulated in my own project.

I also looked at the *Augmented Saxophone Project*, which included three augmented and meta saxophone designs built by the Bent LeatherBand. These saxophones were intended to be used in a virtuosic live performance setting, which meant they also had a focus on carefully choosing and placing sensors that wouldn't hinder the performer. As one of their sensors they used a joystick. This is an interesting way to combat the limited binary of ON/OFF buttons that I believe could definitely be incorporated into my own design.[2]

Another source of inspiration was the video *Effects Pedals for Trumpet - All Pedals Live Performance,* from the channel Woodwind and Brasswind. This is a video of a trumpet being performed with an effects pedal board.[3] My concept is akin to having an effects pedal board mounted to the instrument itself. My design is more ergonomically focused, however the use of effects was something I aimed to emulate in my finished product.

3.SOFTWARE
My programming was done entirely in Teensyduino. I had my main code which read my button and sensor inputs, and then several other codes files for individually testing buttons and sensors, and individually mapping buttons and sensors into my DAW. For my DAW I used Ableton, however I found Ableton's MIDI mapping process to be counterintuitive. Each button and sensor had to be mapped individually with seperate code, which was a time consuming process.

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[1] Leeuw, Hans. (2009). The Electrumpet , a Hybrid Electro-Acoustic Instrument. Proceedings of the International Conference on New Interfaces for Musical Expression, 193–198. https://doi.org/10.5281/zenodo.1177613

[2] Favilla, Stuart, Cannon, Joanne, Hicks, Tony, Chant, Dale, & Favilla, Paris. (2008). Gluisax : Bent Leather Band's Augmented Saxophone Project. Proceedings of the International Conference on New Interfaces for Musical Expression, 366–369. https://doi.org/10.5281/zenodo.1179531

[3] WoodwindBrasswind. "Effects Pedals for Trumpet - All Pedals Live Performance." YouTube. Youtube, October 24, 2017. https://www.youtube.com/watch?v=8a0TFXrVL8Y&ab_channel=Woodwind%26Brasswind.

4. HARDWARE

4.1.French horn

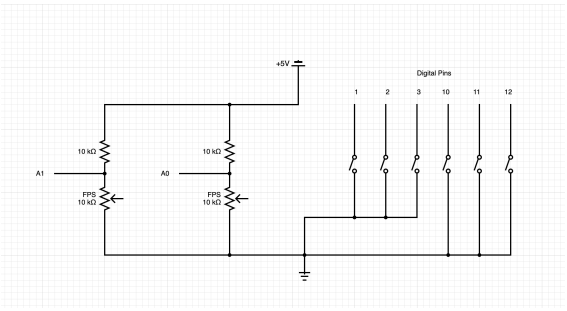
If one were to repeat this project it's important to note the horn model as all horn models differ in size and wrap (the way the piping is arranged). The horn I was using was an Alexander 103. It's a double horn with a Kruspe-style wrap and well lacquered surface. My design for how the electronics have been mounted to the horn may have to be changed on a different horn. If I were to transfer my prototype to a different horn I would likely have to change the dimensions of my 3D printed components to have them fit comfortably.

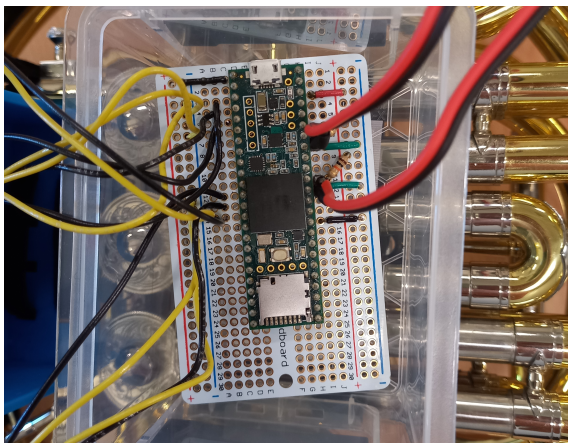
4.2.Micro-controller

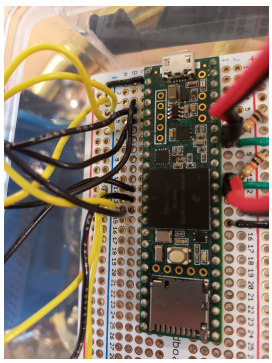
I used a Teensy 3.6 Development board for my micro-controller. This board uses the Arduino + Teensyduino 3.6 software. The Teensy was placed inside a box on top of the F horn valve slides. The box was strapped to the slides by velcro ties.

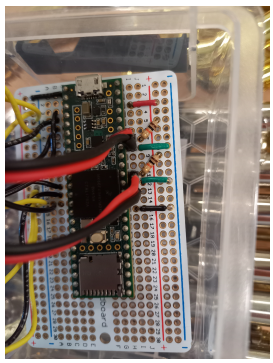
4.3.Circuitry

For all of my buttons, I used the INPUT_PULLUP Teensy extension. The pullup is its own resistor, which meant I didn't have to include resistors with my buttons in the circuit. For my Force Sensitive Resistors I used 10k ohm resistors. My buttons were read by digital pins and my sensors were read by analog.









4.4.Components

SPST LED Illuminated Push ON/Push OFF
Locking on/off
1500V, 16mm diameter
x3 mounted below the keys
x3 mounted above the keys

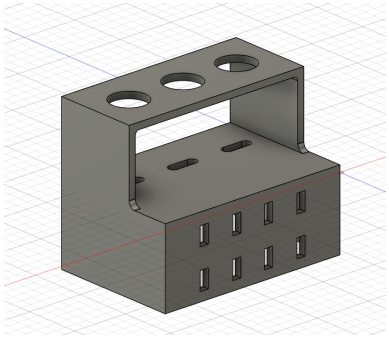
When choosing buttons my specifications were that they had to be small, and that they had to be latching on/off. The small size was so that they would by minimally obtrusive to the player when playing the instrument. Locking on/off would give the player visual and ergonomic clues so that they could easily infer which controls they were using at any given time. As well as this, the horn player is constantly pressing keys to play the horn and with my multiple button set up, the player wouldn't be able to hold down buttons and keys at the same time.

Force Sensitive Resistor
0.5" diameter
x2 mounted inside the bell

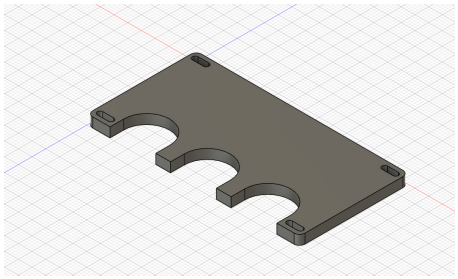
Horn players often use different hand positions inside the bell, so pressing against the sensors is a natural movement. Adjusting the pressure leads to the smooth movement of parameters, allowing the player to have a strong sense of control over the effects. The diameter of the bell where the players hand sits is a little small, so it's important to use small sensors. The ones I chose are 0.5 inches in diameter. The least obtrusive they are to the sound leaving the bell the better, as any adjustments to the size and shape of the bell where the sound exits can cause minor changes to sound quality and tuning. For every effect used, one pressure sensor will control the dry/wet values, while the other controls another parameter within the effect. For example, the second sensor for my reverb effect controls room size.

Mounting Components

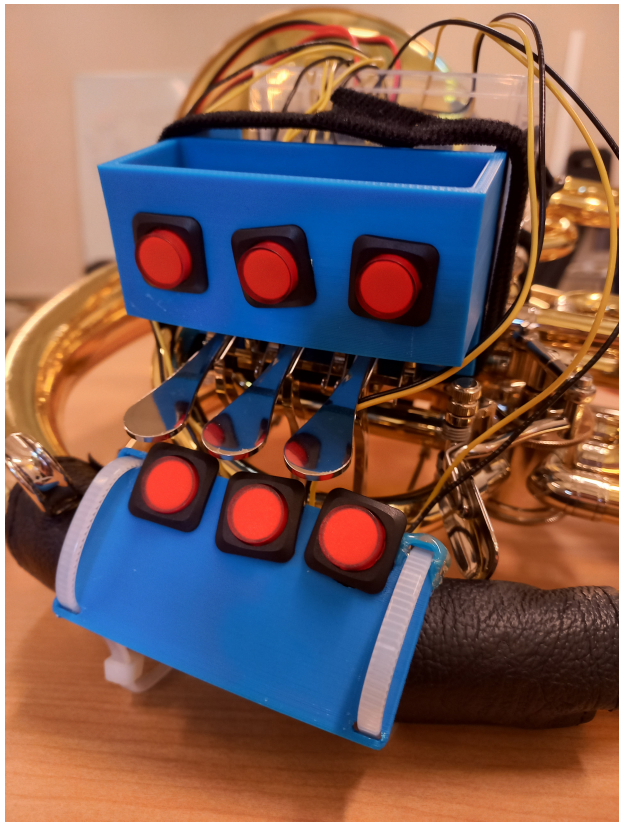
To mount my buttons to my horn, I designed a box an a panel which which I could 3D print. The box is to sit on the metal slats attached to the keys. To make the box removable, I included holes on the base for looping velcro ties through. This way the box could be strapped onto the slats. I also included a velcro strap over the top to keep it steady. On the front of the box there is an overhang where the buttons will sit. This extra arch on the box will sit over top of the keys so that the buttons are positioned closer to the players fingertips. Opposite the holes for the buttons are gaps for the wires to feed through. The buttons mounted on this box control which effects are turned on or off.

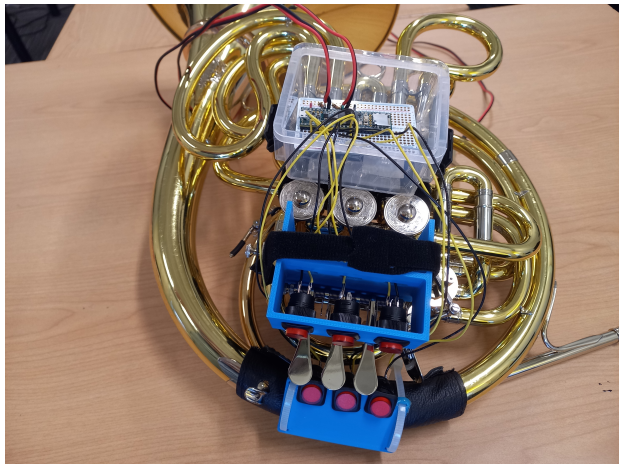


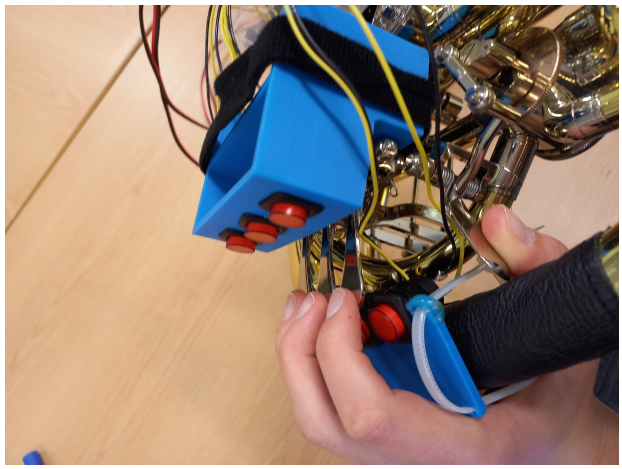
The other component, a panel, is designed to sit against the handgrip. The buttons sit on the top, underneath the keys but imperatively positioned in a way that the keys don't jam against them when pressed. Holes on the top and bottom were used to thread zip ties through to tie the panel securely to the hand grip. To eliminate any damage to the horn, I used a leather hand grip over top of the metal. The buttons mounted to this grip control which parameters are adjustable. For example if the first button is linked to the delay effect, when it is turned on the player can use the pressure sensors to adjust delay parameters, and when it is turned off the parameters will stay maintained at the last value they received before the button was turned off.



My pressure sensors were mounted opposite the players fingers where they naturally rested inside the bell. As a solution to removable mounting, I used double sided tape to attach the sensors to small squares of sponge, then those in turn to the surface of the bell. The sponge layer improved sensory feedback for the player and prevented the sensors being bent on the curved surface of the bell.







5.USE CASE

My prototype is designed for ease of use and to provide the player with as many options for effects as possible. With this being achieved, the best use cases would be in live performance scenarios, or as a tool for contemporary composers looking to collaborate with the horn player. A horn player in a live performance scenario could use the effects controls to enhance improvisation or enforce a modern interpretation upon a historical work.

6.EVALUATION

My goal for this project was to create an electronically augmented French horn. The horn player would be able to play the instrument unhindered by the augmentations. They would also be able to simultaneously control the electronics with as much ease as possible. The controls would be intuitive, and would give the player a high level of control over various effects. To prevent damage to the instrument, all augmentations would be easily removable.

My design meets many of these goals. The mounting leaves no damage to the horn and removing all additions are relatively easy. I tested the ergonomics and usability of my design myself, and with a fellow horn player with limited experience with electronics. In terms of usability, the electronics were easy to understand and control. After a few minutes of practice, both I and the other horn player were able to control the effects while simultaneously playing. However the ergonomics could be improved upon. We both found the hand grip panel and the buttons to be slightly too big. Having small hands, we both struggled to reach the keys and upper buttons with ease, though it was possible. Smaller buttons and a panel with a slightly smaller width could easily combat this.

The effects, when used in combination, did allow the player a high level of control over the sound they were producing. When being used in a performance scenario, the effects mostly responded as expected, however sudden adjustments to the pressure sensors would occasionally cause feedback or pitch modulation when multiple effects were in use. It was entirely possible to control when this occurred and gave the player more options in creating their desired sound. However my design only allows for three effects to be used, and even when put in combination this is limiting to a horn player or composer who may want to be more specific in the soundscape they create for the listener. My button system could potentially use more effects with smaller buttons, but this won't be without sacrifice to the intuitiveness of the controls. Through the use of potentiometers, or even joysticks like in the *Augmented Saxophone Project.*

Ableton also performed as expected. Once it was properly mapped and set up, Ableton was an effective DAW for this project and provided many options and controls for my effects. However I would definitely be interested in looking into other DAWs in future as the mapping system in Ableton was counterintuitive and prone to errors. When trying to map multiple buttons to the effects at once, Ableton was unable to differentiate between the different buttons, resulting in me having to write a new code that would map one button at a time. When mapping my sensors, Ableton also failed to map the MIDI values it was receiving to effect parameters. It would flip the values so that 0 became the maximum value, which meant I had to go back into my code and map my values to MIDI the other way around.

7.FUTURE WORK

If this project were to be picked up again, my first recommendation would be to thoroughly research how the horn is played. My design focuses on utilising the players hand movements, both at the keys and inside the bell. While having buttons around the keys is intuitive to the player and provides some options for effects, I believe that providing sensors for the effect controls inside the bell could potentially be a more effective placement. Horn players use a technique called 'hand-stopping' where they press their hand into the bell to stop the sound from coming through. This causes pitch modulation and a change in sound colour. This technique in combination with sensors such as pressure sensors could be utilised to create a higher degree of control over effects and sound colours. However, it's important to note that this could limit the use of the mute, which is a common tool used by horn players when changing sound colours. Other sensors I considered using when creating my design were sensors that could read air pressure, and sensors that could read objects in a space. For example I believe a lot could be done with the readings you might get from the air pressure the horn player puts through their horn. Or if a horn player were to perform in a space, they could move the horn or even their whole body around that space and have their position read to create a variety of effects.

If I were to recreate this project again in future I would like to smooth out my parameter adjustments. When a button on the handgrip is pressed (say the one for reverb), the effect will read the values it's receiving from the pressure sensors. When that button is switched off the effect will hold the last read value from when the button was on. The problem arises when the button is pressed on again. The parameters will instantly switch to the new value being read by the sensors. I would prefer a slower and smoother transition to the new value.

I would also make my mounting component on the handgrip smaller, and if possible, find smaller buttons as well. I believe smaller buttons will make holding the horn and controlling the keys much easier for the horn player, and would increase the fluidity with which they can play the instrument.

My last adjustment would be to experiment with DAWs outside of Ableton. If someone were to repeat this experiment and use more components that required MIDI mapping, I would definitely recommend looking for options outside of Ableton that allow multiple components to be mapped at a time.

8.REFERENCES

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