

Dual Glove Air Bass

Ying Chen, Pranathi Gummadi, Niranjan Jayanth

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TA: Michael Genovese

1. Introduction

1.1 Objective

As a musician in the 21st century there are many technological tools available to assist the learning process. However, most of those tools are software based and are unsuitable for training muscle memory. This inability to convey, arguably, one of the most important parts of the musical experience impedes the musician's ability to practice reliably on such devices. Therefore, individuals must rely on the traditional method of carrying fragile, cumbersome instruments to and from various locations. The act of repeatedly transporting a heavy instrument can potentially damage the instrument itself. Medical studies show that 12% of 507 musicians developed tenosynovitis, where a majority were the result of carrying heavy instruments [1].

Our proposal for remedying this problem is to develop a portable electronic device that replicates the physical characteristics of the instrument without the physical medium. For this solution, the inspiration was drawn from the concept of "air guitar", a performance art in which an individual pretends to play an imaginary instrument with accuracy. In this specific case, we will be implementing a wearable device capable of generating audio output and replicating the stylistic techniques for playing a bass guitar.

1.2 Background

Success in any musical endeavor is a mental mastery over an instrument or voice. The first mental challenge many musicians face is the playing of music without notes. The evolution of that mastery is the mental mastery of an instrument without the physical instrument itself. In one study meant to observe the effects of both mental and physical practice with regards to pianists, many advantages of mental practice were posited and agreed upon. Firstly, it is equivocally agreed upon that mental practice offers a method to improved highly skilled performance. Further, the switching between mental and physical practice as a general practice strategy is suggested to be more effective than simple physical practice [2]. Since this product is a merging of mental practice (psychomotor understanding of the dimensions of a given instrument) and physical practice (auditory feedback upon practice), it offers a harmonious blend of the two practice disciplines. The market for such a virtual instrument thus far has existed solely in the VR realm, with products such as GloveOne. However, these products require an existing VR device, such as an Oculus Rift or an HTC Vive, which can set a musician back upwards of 500 USD. The cumbersome and expensive nature of such a solution makes it far less appealing, concerns the air bass seeks to avoid with a portable hardware solution.

The other driving need for the air bass is transportability. Despite recent regulations helping traveling musicians, airlines are not required to store instruments in baggage closets, treating them just as other carry-on luggage, when in fact they are far more fragile than the average carry-on suitcase [3]. Further, it is potentially dangerous to store them in the cargo hold of a flight. The extra troubles that traveling musicians who feel a need to practice are thus rather onerous, and can be alleviated from having a portable version of their instruments. This also allows for quite enjoyable musical experiences that require limited effort to set up at any given time; this novelty is what the air bass seeks to achieve. Much of musicians' muscle memory lies in their fingers, so the novelty of having a product that optimizes those abilities would be quite appealing.

1.3 High-Level Requirements

1. The air bass must be able to sustain through 8 hours of battery-operated playing.
2. The air bass must recall at least 90% of pluck attempts as played notes.
3. The air bass must have at least 90% pitch accuracy on left-hand finger placement.

2. Design

For our air bass, we will be implementing 20 different hand positions and enforcing single note play. Musically this represents the range of one and a half octaves specifically between E1 and B2. This implementation has four distinctive subunits required for execution. At the core of the hardware is a microcontroller unit which is responsible for data management, distribution, and processing. In terms of outputs, our microcontroller will service the AUX speaker module. However, UI display for calibration will be a two-way relay of data where inputs are taken and processed then displayed. Overall power to all subunits will be delivered by the power module.

2.1 Block Diagram

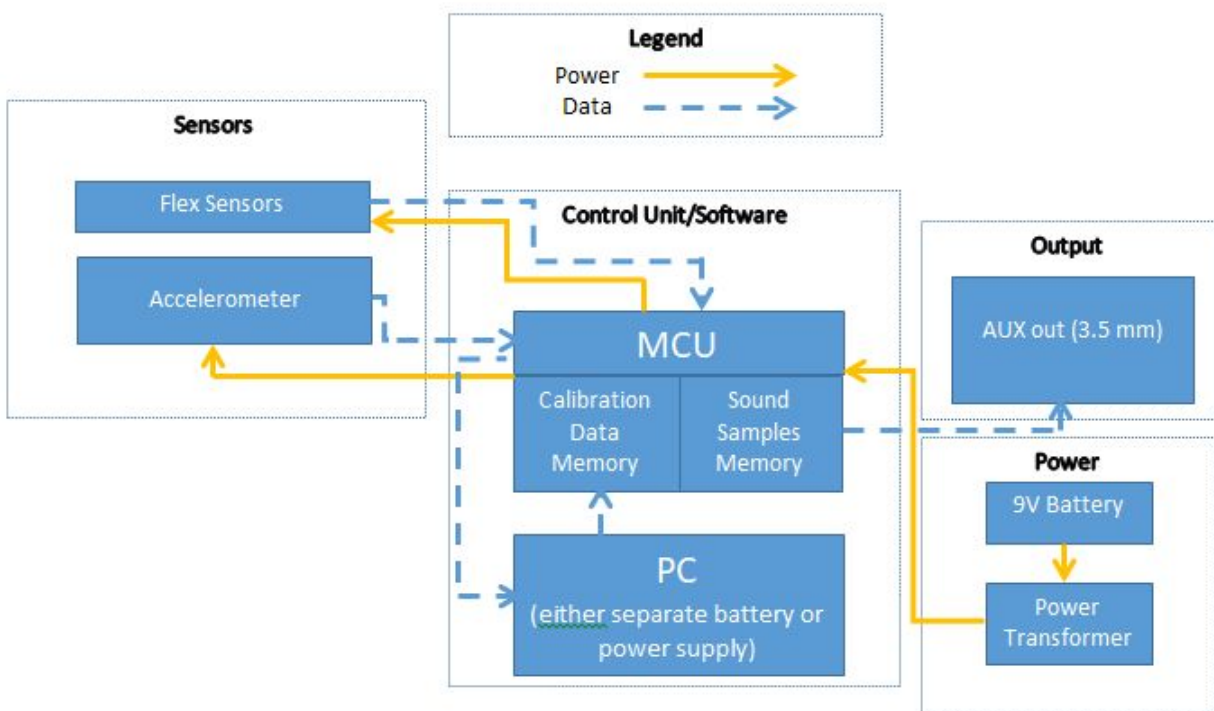


Figure 1: Block Diagram

2.2 Control Unit

2.2.1 Microcontroller

Currently, our initial plans are to use MSP432 microcontroller from Texas Instruments. The MSP432 series is known for its low power requirements and high performance. Texas Instruments provides a large library of technical support documents for UART, SPI, IrDA, and I²C interface protocols. The microcontroller also features a 14-bit ADC and 24 channels for analog inputs. Our project falls under the category of wearable, portable, consumer electronics which is a common application for the MSP432. A 14-bit IEEE's floating point number is capable of representing precise binary values by using 9-bit significant values, 4-bit exponents, and 1-bit for sign. On the MCU there is a total of 256kB of flash memory, 64kB of SRAM, and 32kB of ROM available. There is a 6mA current sink/source for digital inputs. The microcontroller must include an option of an SD card support, needed to store sound samples and calibration data from the PC.

Requirement 1: The controller must support UART, SPI, and I²C.

Requirement 2: The controller must have at least 10-bit ADC resolution.

2.2.2 PC/Software

The PC will be used to calibrate the system before use of the air bass. It will use data points provided upon initial setup to learn the thresholds for each movement (transition between strings and between notes). Since the processing power of the MCU is limited, a PC will be used to run the machine learning algorithm and then communicate via UART back to the MCU. The finalized values will be stored on the microcontroller.

Requirement 1: The software must be able to communicate via UART, SPI or other interface to the MCU.

2.3 Sensors

2.3.1 Flex Sensor

The flex sensors will be used to measure the bend angles in the fingers, indicating the press state of the left hand and the pluck state of the right hand. They will be powered by the 5V rail getting power from a 9V battery. A voltage divider will be used to measure the difference between a given bent state and 0°. For the left hand, the first string will see a finger bend of 90°, the second string will see 120°, the third 150°, and the lowest string 180°. The subsequent voltages will not be hard coded, but used to train the system to recognize different gestures. For the machine learning to be most accurate, we will need the flex sensors to see at least a 0.1 V difference in the target angles.

Requirement 1: The flex sensor must produce voltages distinguished by ± 0.1 V when bent at 0°, 90°, 120°, 150° and 180°.

Requirement 2: The flex sensor voltages at a given angle must not differ more than 50 mV.

Requirement 3: The sensor must not exceed dimensions of 5 cm x 0.5 cm.

2.3.2 Accelerometer/Gyroscope

The accelerometer will be used to determine relative position and determine pluck state. It will be powered by the 5V rail getting power from the 9V battery. The accelerometer will send analog data to the ADC of the MCU to be integrated to find relative position. The MCU will then interpret this and use these inputs as inputs to a state machine to find the next state. The accelerometer and gyroscope will also be used to sense the plucking of the string, based on the rotational acceleration and linear acceleration of the finger, detecting whether the user had the intent of plucking. This will handle the case of a bent finger that is stationary, and thus not plucking the string.

Requirement 1: The accelerometer must have a minimum range $\pm 2g$ and the gyroscope must have a minimum range of ± 180 dps.

Requirement 2: The module must not exceed dimensions of 50mm x 50mm.

2.4 Power

2.4.1 9V Battery

The battery will be used to power the system. Since our project is designed to be mobile, we cannot use a stationary power supply; further, since the components being powered are relatively low-power, we can use a 9V battery.

Requirement 1: The battery will be able to provide at least 200 mA at rated voltage for at least 8 hours.

2.4.2 Power Transformer

The power transformer must be able to supply 3.3V and 5V rails from the 9V battery. The resulting rails must have a steady voltage with little overshoot for sake of not sending more power than allowed to the flex sensors and accelerometers/gyroscopes.

Requirement 1: The rails will be able to provide sufficient power to the sensors for at least 8 hours.

Requirement 2: The step-down power will not exceed $\pm 0.2V$ below or above intended voltages at 200 mA.

2.5 Output

2.5.1 Auxiliary Output (3.5 mm jack)

The output of our system will be the note played by the user. We will be storing sound samples on an SD card and playing them back out to an auxiliary output. This can be plugged into any given speaker. The audible ranges for a human being is 20 Hz to 20KHz.

Requirement 1: The auxiliary output interfaces with the MCU at at least 40 kHz sampling rate.

2.6 Risk Analysis

Potential points of technical failure for the system can be narrowed to two overarching portions: sensors capability and software calibration. Due to the inconsistent play styles between users, inconsistent habits and hand gestures will pose a great threat to the accuracy of our system. While we plan to enforce limitations on the repertoire of recognized motions, these random motions may cause interference. However, our calibration system will attempt to minimize these errors via calculations of repeated data capture. Similarly, the sensors may cause trouble during build, it is common to have inaccuracies due to fickle readings. We plan to integrate over accelerometer data which is known for introducing noise to outputs. The predominant part of our project is position detect and motion recognition. Therefore, if sensors produce a large margin of noise, our classification threshold and error may be significant. In such cases, where the sensors and calibration falter, the overall system may display behaviors of missed detection or false alarm.

The complexity of the gloves pose the critical threat to replication and completion of the instrument. From a management stance, we plan to partition and complete tasks vertically to insure individual feature deliverables ready for independent demos.

In addition to these execution risks, there remains the issue of physical strain on the system due to repetitive testing and usage. Natural movement of the fingers causes wear and tear on the electrical components connected to the glove such as the flex sensors. Considering the prototypical nature of the gloves the priority is to be able to make a functioning glove. The next priority is the durability of the glove given the amount of testing to be done with it. To prevent any malfunctions as a result of physical strain, we will be conscious about the type of materials used and the delicacy with which we set up the electrical components.

2.7 Physical Design

2.7.1 Hand Positions

The table below documents the 20 left and right hand positions that we plan on implementing. This table maps positions back to their coordinates via string and fret.

	E	A	D	G
Open				
1st Fret				
2nd Fret				
3rd Fret				
4th Fret				

Table 1: Hand Positions

2.7.1 Physical Glove - Sensor Markup

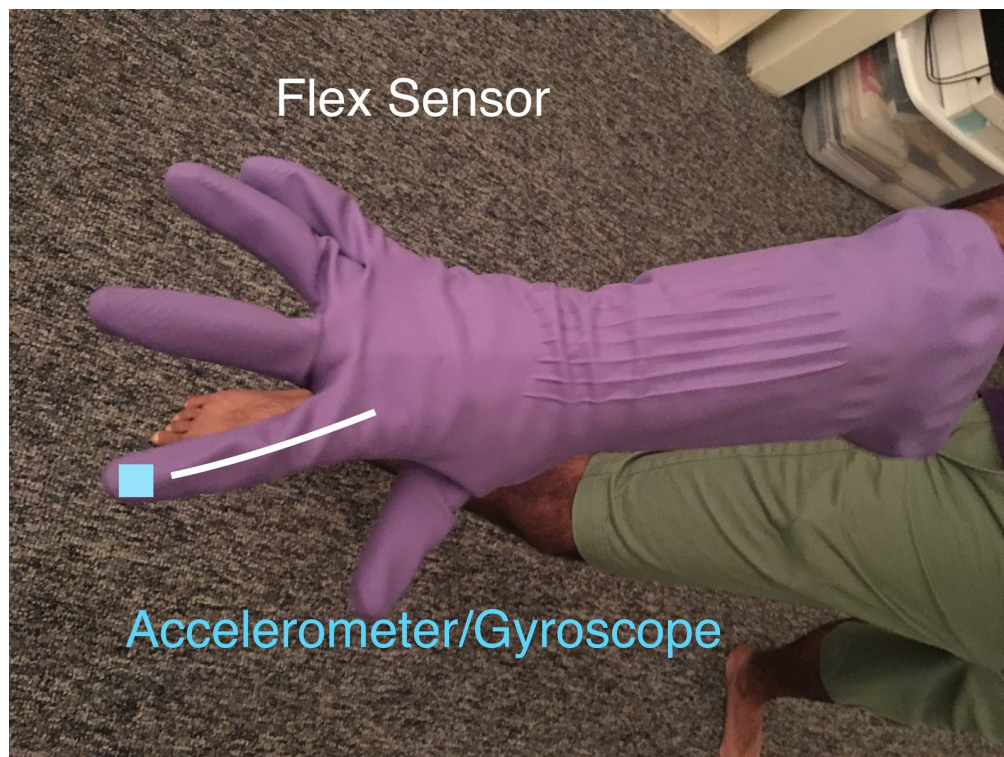


Figure 2: Right Glove Sensor Placement

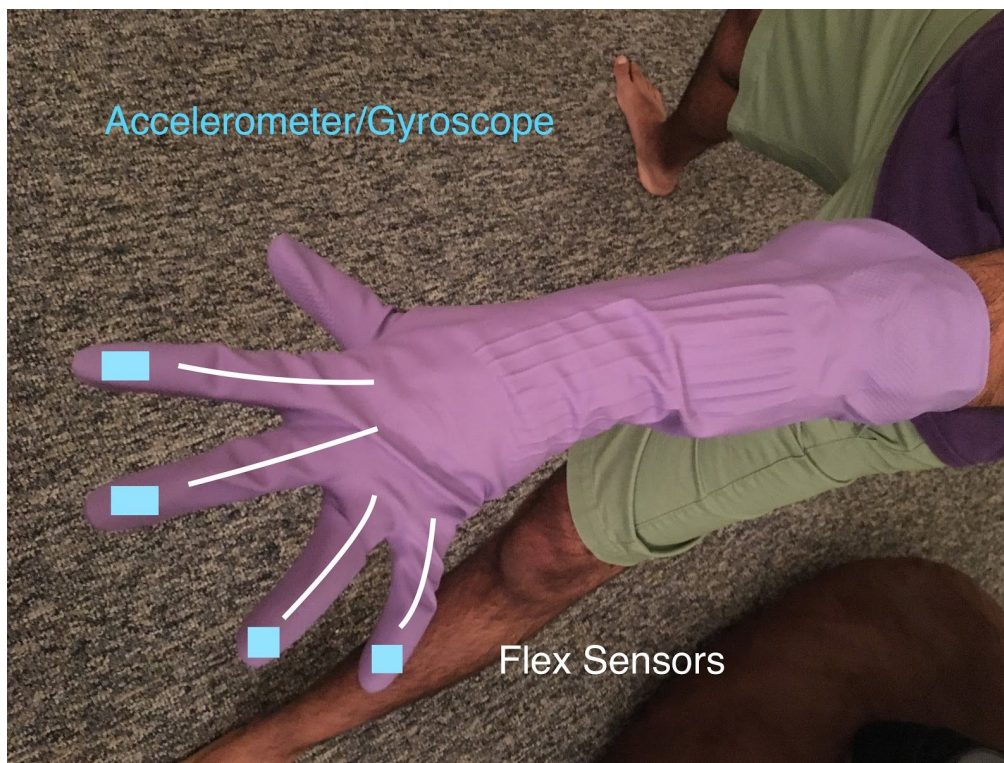


Figure 3: Left Glove Sensor Placement

3. Ethics and Safe

The most relevant safety concern with wearable devices is the physical contact between electrical equipment and the user's body. Therefore, insulation and build must be of the utmost quality to prevent potential harm. A possible physical safety concern could be the potentially heavy weight of the glove causing repeated stress and strain on fingers and wrists. Continued use could result in medical conditions such as carpal tunnel or wrist tendonitis. We will execute the project while in agreement with IEEE's code of ethics obligation number 9, "to avoid injuring others, their property, reputation, or employment by false or malicious action" [4]. We understand these physical concerns and will take preventative during testing and building.

As the market for wearable technology expands, government regulations are put into consideration for testing product safety. The FCC strictly monitors the industrial and consumer products that make use of RF and electromagnetic waves. Specifically, in the March 2013 vote, the FCC decided to reassess its limits on permissible absorption of radio frequencies [5]. According to Kenneth R. Foster, professor of bioengineering at the University of Pennsylvania, safety concerns due to electromagnetic radiation is negligible due to devices operating at lower power requirements [6]. To support the FCC's reexamination of their policies, Professor Foster also mentions that the FCC's regulations have yet to be updated to reflect current technological advancements [6]. Due to these findings, we can assume that the possibility of repeated exposure to RF/EM due to usage as potential source of harm to be minor.

In addition to miscellaneous electronic components that may require physical contact, we will utilize a dense battery.

4. Bibliography

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