Imperial College London
Department of Electrical and Electronic Engineering

Final Year Project - Interim Report 2015

PAWS
Programmable And Wearable Sound

Project Specification

'The development and evaluation of a novel and unusual musical instrument to be constructed using a 3D printer.'

The aim of this project is to research the current market and design a new musical instrument that integrates the traditional definition of being able to generate sounds with modern studio production methods and technological trends such as sampling, synthesis, and motion capture, in an effort to increase functionality while maintaining musical expression.

The product itself will be comprised of a wearable hardware sensor board and a counterpart software interface to control the audio output of each board. The sensor boards will be wearable through custom-designed 3D printed housings so as to meet the brief. The instrument will be produced in repeating production cycles, as per the iterative waterfall model, with each cycle building upon either the functionality or the aesthetic design. The instrument will also be evaluated in terms of usability with musicians and in terms of marketability against competing ventures.

Project	A Novel & Unusual Musical Instrument
Name	Kartiksinh K. Gohil
CID	00692607
Supervisors	Prof Robert Spence, Dr Mark Witkowski
Second Marker	Dr Christos Papavassiliou

Contents

1 Background

This final year project has a short brief (shown in italics in the Project Specification section) and is open-ended, relying more on a creative musically-oriented approach rather than the usual best-fit engineering solution.

The definition of a 'musical instrument' has evolved drastically over the years, ranging from traditional acoustic instruments (*piano, violin*) to electrical (*guitars, keyboards*), electronic (*synthesisers, Theremin*), and even virtual instruments that exist purely as software models in audio production tools.

The current music market has been overtaken by new computer vision and wearable technologies, giving way to products such as the Mi.Mu[1] gloves and DrumPants[3].

The idea of capturing motion through worn sensors or distant cameras allows the user to integrate their bodies with electronic systems. Musicians can make sweeping gestures to produce and control sounds, much like was traditionally done with mechanical instruments. With the initial introduction of electronic instruments, musicians became confined to button-based keyboards and drum machines, and later to point-and-click software on computers.

New technologies have allowed the modern musician to let the motion of their body contribute to their overall sound but they still seem to be fairly restrictive. The Mi.Mu gloves, as shown in Figure 1, allow the user to generate music simply by moving their hands. They can emulate playing a drum kit with their hands and the gloves will send MIDI signals to a digital audio workstation, which will produce the correct sounds in response to the user's 'air-drumming'. The gloves can also be used to control functions on sound, such as altering amplitude, filtering and even adding effects like Reverb, all through a pre-determined hand motion. This technology, however, is incredibly expensive. Selling at nearly £5000[2], these gloves are not accessible to the average person. It also requires other software tools for it to interact with, meaning that the user is in fact confined to a particular physical workspace, be it a studio or a live stage.

Figure 1: Mi.Mu Gloves[2]

DrumPants is another product that utilises wearable sensors to control sounds. The instrument, shown in Figure 2, uses sensor strips that attach to your clothes and connect wirelessly to a central controller. The strips contain pressure sensors that, when hit, send MIDI data to the controller, which can be set by the user to play any virtual sound in response, such as a drum kit or a piano. This controller can output audio directly to a speaker or can send the raw MIDI data to a compatible computer program.

Figure 2: DrumPants Basic Kit[4]

Currently on pre-order from $129.99[4], this instrument allows the user to program each sensor to play any pre-recorded sample sound, and is also being marketed to remotely control video games. The functionality, however, is limited to contact via pressure, and slightly malforms the user's experience by again restricting them to a particular physical area at any given instance. Even though this physical workspace, or the area where the sensor is located, is movable between instances of use, it still limits the musician's ability to improvise and requires an inordinate amount of setup time before playing can commence.

A third product, not specifically designed for music but important nonetheless, is the Ring[5] by Logbar Inc. The Ring has the capability of controlling any web-linked interface with gestures through an Android or iOS App. It is designed for the user to assign gestures to specific features, from controlling music playout on a smartphone to opening a set of shower curtains (provided they have internet connectivity). The idea behind the Ring is that it allows a user to directly interact with the world around them through a portable wearable sensor with apparently no physical limitations. The concept of this device, in its functionality and freedom of use, would greatly enhance a musician's creativity if applied to the world of sound.

Figure 3: Ring by Logbar Inc. [5]

Based on these new products, I aim to produce a musical instrument that heads in the direction of user-programmable electronics that is portable and not restricted to a physical workspace in the way that most other motion-based products (especially computer-vision related) are. The musical instrument should allow the user to define the manner in which they wish to produce sounds and should allow them to use the range of their entire bodies in the process without introducing any physical or mental limitations.

2 Product Concept

The musical instrument I will be building will be based around the concept of programmable, wearable sensors. Firstly, the instrument shall use an array of sensors, such as audio (microphone) or motion (accelerometer/gyroscope), to capture and control sound. These sensors should be wearable by the user, most likely through bespoke 3D printed housings so as to meet that particular aspect of the project brief. The ability to wear these sensors in any location will increase the adaptability of their use, as well as removing the restrictions of a fixed physical environment. These sensors should also be programmable by the user in order to complete any given task. The user should be able to perform functions such as recording their voice, em-

Figure 4: User Level Design

ulating a real live drum kit, mapping a tempo, and even harmonising their singing with virtual instruments, all by programming the sensors in various ways. Figure 4 shows a user-level diagram of a sensor array [PAWS Board] sending information wirelessly to an interface on either a computer or a smartphone and consequently producing audio.
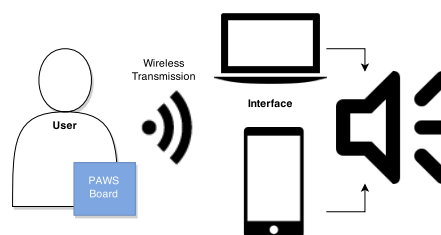
My instrument, entitled PAWS [Programmable And Wearable Sound], will in fact have both a hardware and software aspect to it. The hardware shall be a number of standardised sensor arrays that can be attached to any part of the body through custom 3D printed housings, which send their recorded data to a software interface, be it on a laptop or on a smartphone. This interface will allow the user to control the function of each PAWS Board and record the output audio to file, as shown in the concept design in Figure 5.

The focus of this product is not on building perfect sensor arrays with minimum latency, or on developing a new signal processing technology, but rather on conglomerating the various existing ideas on the market into a single instrument that can be used by musicians in any way they like to accomplish any given task. The key features of this instrument, therefore, should be flexibility and simplicity of use.

Figure 6 shows sketches of how a PAWS Board may be put to use. Currently, the idea is for the PAWS Board to be used in three separate ways. The first and simplest is to simply record vocals or any other sound that a PAWS Board may capture through its microphone. The interface should be able to obtain the input from the Board in question and save it to a file or play it back for the musician to listen to through the interface's built-in audio output. The second functionality the instrument should have is to be able

Figure 5: Concept Design for a smartphone-based Interface

to trigger sample sounds based on percussive motion. Figure 6 shows a finger with a PAWS Board attached tapping a rhythm on a random surface. If the Board has been programmed to trigger a sample such as a drum sound (as demonstrated in Figure 5), the user should be able to play a virtual drum kit through any given surface. Figure 6 also shows a hand with another PAWS Board attached at the wrist controlling select parameters of the output audio through motion gestures. This would be achieved by programming a range of motion to adjust a specific parameter such as Amplitude or Pitch.

Further designs for the PAWS Board include allowing a musician to set a particular tempo by tapping their feet (with a PAWS Board attached), which could also aim to quantise any other sounds that they produce, thus improving the quality of the generated sound. The sample trigger function could also be used to let a musician harmonise with themselves. For example, if they were singing into one PAWS Board and tapped another onto a surface, as if playing a piano, the instrument would trigger a piano sample at the same pitch as their vocal melody. Multiple PAWS Boards for sample triggering could be used to allow a musician to play entire chords in harmony with their voice.
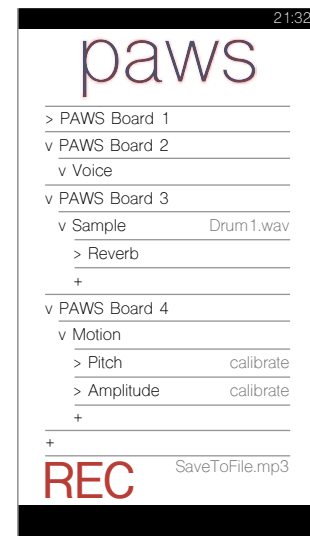
IMAGE MISSING -> finger tap + hand motion

Figure 6: Concept Sketches of Usage

3   Objectives & Specifications

AND REQUIREMENTS

list of things this instrument should be able to do, might be able to do, and could potentially do by the end of the project

4 System Design

block diagrams of sensors and interface in terms of functions, still very high level
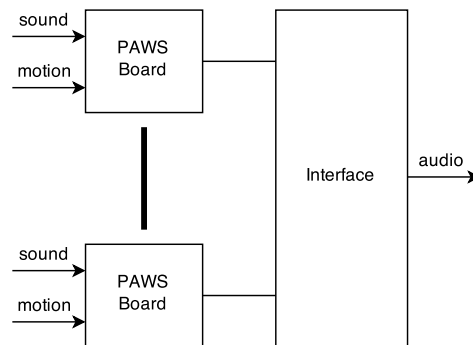
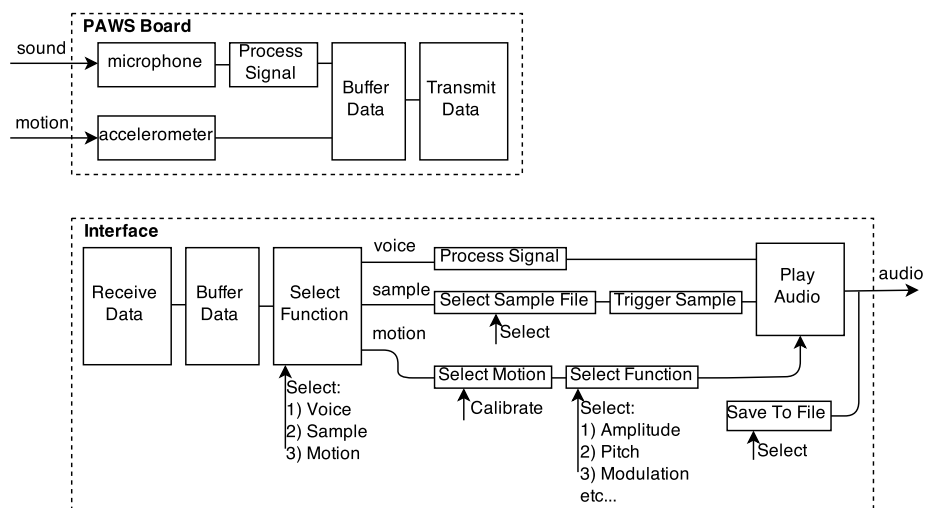Figure 7: System Design - High Level

Figure 8: System Design - Low Level

5　Hardware Design

OVERALL HARDWARE DESIGN

block diagrams of sensor boards and their components, what they should do, and how they should work

SUBSECTIONS OPTIONAL BASED ON TIME!! CAN SHOW PROTOTYPE 0.1.01 CIRCUITS

5.1　Microphone Circuit

circuit diagrams, connected to arduino. how it works, what it outputs.

5.2　Bluetooth Circuit

circuit diagrams, connected to arduino. how it works. what it does.

6   Software Design

OVERALL SOFTWARE DESIGN

what the interface should be able to do. what it should look like. how it connects to hardware and what it outputs, and how the user can interface with it.

FLOW CHART OF SOFTWARE PROCESS - MICROCONTROLLER AND INTERFACE

7   Project Timeline

EXPECTED DELIVERABLES with times, including reports and presentation

7.1   Implementation Plan

list of prototype deliverables all prototypes 0.1.xx and their features, that way we can use their names as a way of evaluating progress

7.2   Evaluation Plan

8　References

[1] Mi.Mu Gloves. *Mi.Mu: About.* http://mimugloves.bigcartel.com/mi-mu-bio/ (accessed 24 Jan 2015).

[2] Mi.Mu Gloves. *Mi.Mu Collaborator Gloves.* http://mimugloves.bigcartel.com/product/collaborator-gloves/ (accessed 25 Jan 2015).

[3] DrumPants Inc. *DrumPants.* http://www.drumpants.com/ (accessed 24 Jan 2015).

[4] DrumPants Inc. *DrumPants.* https://legacy.trycelery.com/shop/drumpants/ (accessed 25 Jan 2015).

[5] Logbar Inc. *Ring.* http://logbar.jp/ring/en/ (accessed 25 Jan 2015).