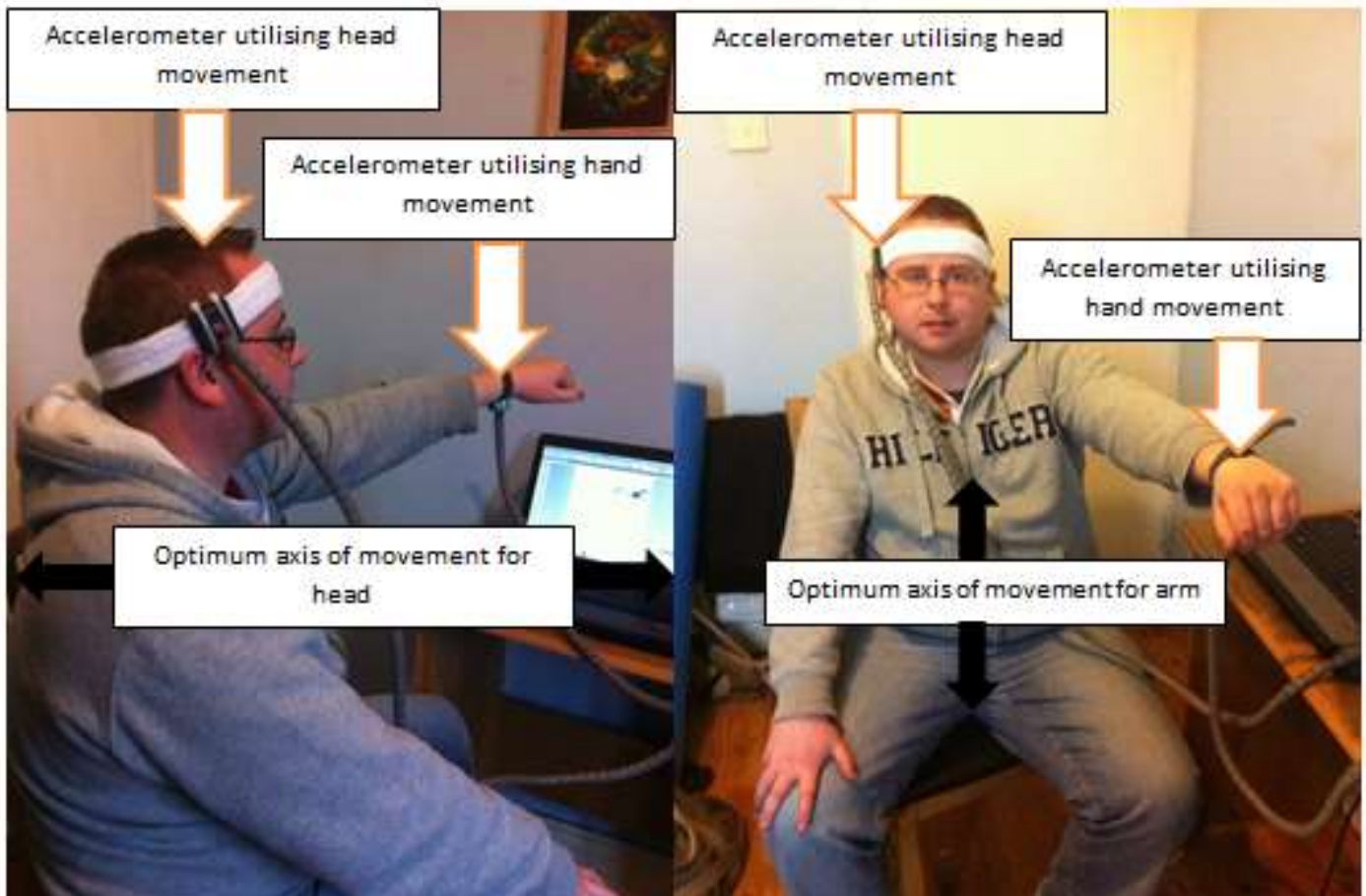


Design and Development of an Assistive Technology Music System for Sufferers of Cerebral Palsy



Enablement Product Music-ability™

Final Year Capstone Project

Bachelor of Engineering Honours Level 8

Industrial Partner: Sound-Out



Ireland's National Music Education Programme
A Music Network initiative, funded by U2 & The Ireland Funds

SYNOPSIS

Music is something which is engraved into our culture. Music gives us a sense of community, culture and family and is such an integral part of our lives that it can often be taken for granted. However, not everybody has the ability to create music. This project strives to bridge the gap for people with severe disabilities to express themselves musically. The design, development and testing of a viable method for creating music for sufferers of cerebral palsy, utilising subject available movements, is undertaken. The developed generic assistive music technology system is readily adapted to a wide range of disabilities.

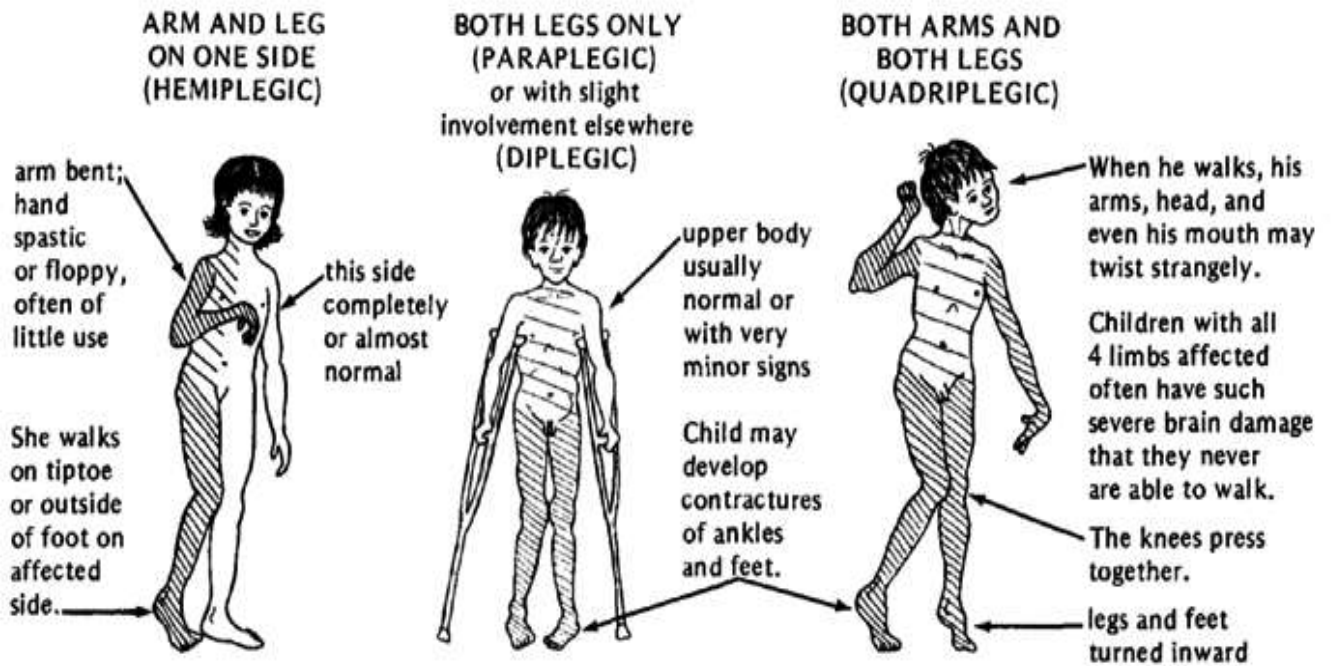


Figure 1 - Levels of Cerebral Palsy (2)

Abstract

This project is concerned with the design and development of a viable method for creating music utilising the available movements of a particular subject with hemiplegic cerebral palsy - but leads to the development of a generic method of music creation to suit a wide range of disabilities.

A systematic design approach is adopted to conceive, design and optimise the novel music system - Music-ability™.

Iterative prototype design, development and extensive testing is successfully undertaken.

The developed hardware and software system efficiently converts head and arm movements into corresponding notes and sound effects.

Through extensive liaison, feedback and approval from the subject and music teacher, the created assistive technology music system is optimised and tailored for the unique wants and needs of the subject.

The system has been tested and calibrated and formal handover (including supporting documentation) of the Music-ability™ Prototype to the subject, Christine, her parents and the SoundOut organisation took place on Monday 12th May 2014.



Figure 2 - Handover of Music-ability™ Prototype
(Photo reproduced with kind permission of Christine and Parents)

The developed generic assistive music technology system Music-ability™ is readily adapted to a wide range of disabilities.

Introduction

Cerebral palsy can be defined as a central motor dysfunction affecting muscle tone, posture and movement resulting from a permanent, non-progressive defect or lesion of the immature brain. Resulting limits in movement and posture cause activity limitation. The main aim of the project is to take advantage of the available movements of a person with cerebral palsy to create a more sophisticated and enjoyable experience when playing music. It is planned that the developing system will allow the subject to explore different rhythms and allow them to play a range of notes and keys the same as any other instrument. This instrument will be electronic and will be implemented by simple movements. This project will study the range and strength of movement of one particular student and in turn create a generic instrument which would allow patients of similar mobility to be able to play. Currently there are problems with the assistive music technology available. In the case of the “sound -beam”, which is an ultrasonic sensor which detects hand movements to play notes, all notes have to be consecutive and note selection is difficult. The “magic flute” is an instrument which requires head movement and blowing – but does not cater for a student with limited lung capacity and is not suitable for a person with cerebral palsy. This project strives to take full advantage of the available assistive technologies such as eye-gaze, sound-beam and the magic flute and incorporate these technologies along with other design features such as haptic feedback, integrated software and simplistic controls into a system of creating music from which the subject can practise and learn from – similar to any popular musical instrument.

Project Aim

To create a new adaptive technology system to take full advantage of available movements of the subject - creating relatively sophisticated music, which can be easily used and enjoyed by student and incorporating the ability to play along with others.

Project Objectives

1. Assess and characterize the range of motions of the subject.
2. Research and critically assess assistive technology.
3. Design a new assistive technological system to address needs of specific subject incorporating existing technology with additional software and hardware elements.
4. Experimentally determine the effectiveness of the new system and its ability to integrate with other musicians.
5. Evaluate and optimise design based on feedback from subject and music teacher.

Literature Review

Cerebral Palsy

Cerebral palsy is a group of disorders that can involve brain and nervous system functions, such as movement, learning, hearing, seeing, and thinking. A non-progressive and permanent disorder, cerebral palsy is caused by injuries or abnormalities in the brain. The majority of these problems are caused when the baby is still in the womb, but can also occur during the first two years of life. The affected area of the brain is known as the cerebrum and the problem may involve connections between the cortex and the cerebellum

Molnar (1) argues that symptoms can greatly differ between people with cerebral palsy. Symptoms can be very severe or mild, can only involve one side of the body or both and may involve both arms and legs. Depending on the subject, arising issues may include tremors, loss of co-ordination and speech problems. The level of spasticity and also the type of dyskinesia (movements) effected are means of classifying the cerebral palsy.

Due to major differences in symptoms of subjects, this product is initially designed for a patient with a specific set of limitations. The subject has neck movement and some arm movement, which will be utilized and converted into a system of creating music. In turn, a generic instrument can be created to be used with people of similar mobility but which also can be adjusted and calibrated to suit different forms of cerebral palsy and other disabilities.

Current Adaptive Technologies

Eye Gaze

Eye gaze (3) is a unique system of interacting with a computer; it allows people with complex physical disabilities to easily navigate through an operating system. The system is controlled by the eyes of the user - actions such as synthesising speech, controlling environments, operating a telephone and sending e-mails are assessable to the subject. The system works via a camera mounted below the monitor of the computer, which observes the users eyes via the reflection of light off the cornea. The image processing software continually monitors the video of the eye and in turn determines where the subject is looking on the screen.

As with any new technology there are limitations of use. The subject may not be capable of maintaining eye focus long enough to make eye-gaze selections, often caused by Nystagmus, which is constant involuntary movement of the eyeball. Another problem is that eye gaze tracks one eye and if a subject has alternating strabismus, the eye gaze does not operate as required. Other problems arise due to vision problems and if the subject has involuntary head movement.

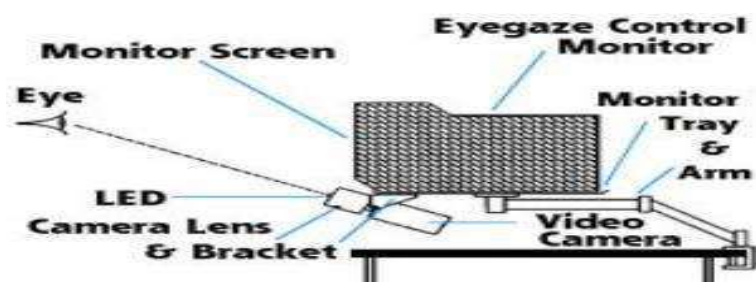


Figure 3 - Eye Gaze System (3)

Eye gaze could be used as a method of altering music using software such as Reason or Ableton. Different selection of instruments, sound effects and keys could easily be assessable. However as a means of generating music it would not be very expressive and would not give the “feel” of an instrument. Furthermore, repetition of eye movement may cause eye strain and requires a lot of concentration.

Magic Flute

The magic flute (4) is an electronic wind instrument designed to be played without the use of hands. The magic flute is placed on a stand and is allowed to swivel vertically, allowing the subject to reach different notes. An internal gyroscope detects the angular position of the magic flute and converts that into a note or pitch. The magic flute is fitted with a sound card for sound creation, but can also be connected to keyboards or even basic speakers. The volume of the note is controlled by the strength of the breath. The control module is used for changing scales and sounds. Menus can also be accessed by “sipping” and “puffing” into the mouthpiece.



Figure 4 - Magic Flute (4)

The magic flute has many associated limitations. The apparatus cannot be used if the subject has a limited lung capacity or poor control of breath. If the subject has tremors, maintenance of contact with the mouth piece is very difficult. Another problem is that the subject needs good neck control and good posture. The mouth piece also has to be cleaned regularly.

This magic flute could potentially be used as a method of creating music for the subject - however it would require a large number of significant alterations to make it more suitable. The design of a new system of creating music is more feasible and practical, incorporating magic flute type features into the final design such as using a gyroscope, a programmed control module and MIDI (musical instrument digital interface) output.

Sound-Beam

Sound beam (5) operates by converting body movements into sounds, does not require any special equipment and is suitable for people with disabilities to create music in a safe manner. The sound-beam consists of an ultrasonic sensor which detects the proximity of the object and converts this into a note. Generally, the closer the object is to sensor, the higher the note. The sensor is configured to allow only notes in the selected key to be played. In this sense, the musician can play any note and this play would fit in with other instruments.

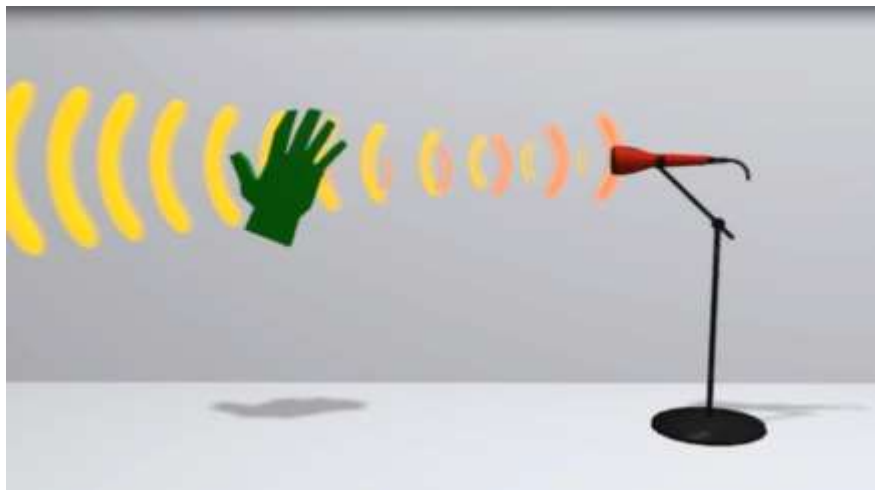


Figure 5 - Sound-beam (5)

The main problem with sound beam is that the music created is not very sophisticated and it gives the impression of making noises as opposed to creating music. Accuracy is a big issue because it is very difficult to determine exactly how far away to place the object to create a certain note. Furthermore, the skipping of notes is not achievable.

One of the main aims of this project is to create more sophisticated music for subjects. The utilisation of sound-beam for this purpose is not suitable. Sound-beam requires a high degree of calibration to be applicable and one sound-beam is not sufficient. The sound-beam does not take full advantage of the available movements of the subject. However, the use of an ultrasonic sensor and creating parameters, which stop the user from playing notes in a different key, may be useful for this project.

Basic music theory

Aston and Webb (17) suggest that if musicians are to play together, then a key has to be predetermined. This key is the note around which the whole song/tune revolves - also known as the tonal centre. There are twelve possible keys in music in which a particular piece of music can be played. Within these keys, there are eight notes which can be played, for example in the key of D the notes D,E,F#,G,A,B,C# and a higher D can be played. In relation to this project, a system where the user can predetermine the key and only play notes within this key is to be incorporated. Another system, which could also be used, is if sound effects were used instead of notes to allow for the simulation of percussion instruments such as drums or bongos.

MIDI (musical instrument digital interface)

MIDI is a protocol which allows digital instruments to interact with one another and computers. A MIDI file contains no notes - but contains instructions describing the notes played in a performance and other related information. A large number of software applications are available which use the MIDI interface. The most widely used is the sequencer. Sequencers allow the computer to record, store and edit MIDI data. Sequencers contain multitrack recording functions, this allows users to mix and edit MIDI files in a virtual studio environment. Ableton, Reason and GarageBand are software packages which would allow the user to have access to many different synthesised sounds for live or recording purposes.

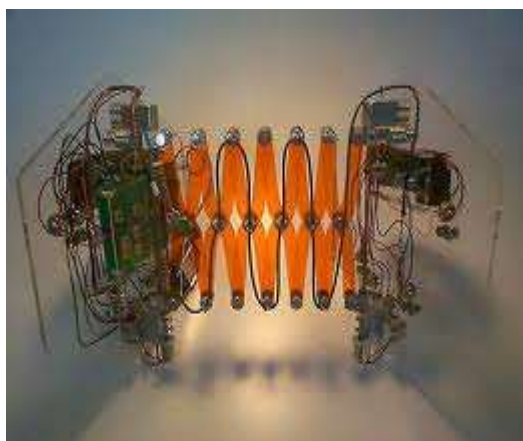


Figure 6- Accordiatron (17)

Gurevich, von Muehlen (16) have shown that an instrument can be created which gives a MIDI output, by using the gestures of the musician with real time signal processing. This approach allows for sufficient expressiveness and the control which is needed for interactive music. This paper highlights that there is a gap between electronic instruments and traditional instruments in terms of articulation, pitch and loudness. The accordiatron (17) is based on a traditional concertina and bridges this gap in terms of pitch and loudness.

The proposed output of this project is to have a MIDI file, which could be inputted in music software to mix the music of different instruments together in a live environment but also to save work of the sessions and to edit the music. Converting the file to MIDI is a crucial aspect of this project to allow the subject to express themselves musically.

Systematic Design

A systematic design approach was adopted by the author in liaison with disability enablement organisation SoundOut to advance the goal of the project to provide a product that allows a subject with cerebral palsy to create sophisticated music with basic movements. The detailed systematic design including developed Objectives Tree, Establishing Functions Setting Requirements, Morphology and Quality Function Deployment Chart developed by the author is presented in Appendix C.

Evaluating alternatives

An evaluation was completed for different systems that could be used to analyse the movement. This evaluation can be seen in table 1, where a 3 axis accelerometer, gyroscope and ultrasonic systems are compared. It is shown that an accelerometer is clearly the best method for the music creation system. The weights of each of the objectives were determined by the author in conjunction with the disability enablement organisation SoundOut.

Where ● = better

Where ○ = same

Where ◇ = worse

Table 1 - Evaluating Alternatives J.Fogarty 2014

Objectives	Weight	3-axis accelerometer	Ultrasonic sensor	Gyroscope
Ease of use	16	○	○	◇
Cost	10	●	◇	◇
Range	7	●	◇	◇
Accuracy	17	●	◇	◇
Uses available movements	18	●	◇	◇
Feel of a musical instrument	8	◇	◇	●
Easy to attach/remove	5	◇	○	○
Response time	14	○	◇	○
Sophisticated music creation	13	●	◇	◇
Alter sound expressively	10	●	◇	◇

Proposed Design

- Dual three axis accelerometer system to be used for gesture recognition.
- Accelerometer to be placed on the wrist for primary motion detection.
- Second accelerometer to be placed on the head of the subject for secondary motion detection.
- LabView to be used as a means of converting signal to note.
- Accelerometers will be wired to a data acquisition module, which connects to a computer via USB
- MIDI output to be generated and displayed on screen
- Output can be altered on a music software package for live or recording performances.

Detailed design

Preliminary experimentation

After systematic design, it was concluded that a dual 3 axis accelerometer system be developed. To determine the parameters of these accelerometers, two experiments - designed to quantify the maximum acceleration of the arm and range of movement - were set up.

Another important aspect of the developed experimentation was to highlight the best method of creating the music with the component. For example, would utilisation of the accelerometer just in a certain direction be most beneficial because of the maximum acceleration in that direction or would combinations of movements be easier for the subject to complete. Each experiment was carried out with the permission of the subjects and in a group environment - no pictures were taken.

These experiments were carried out on two subjects with quadriplegic cerebral palsy. The main reason for this was to see if there was a significant difference in the maximum acceleration which both subjects can produce.

An accelerometer was attached to the arm of the subject which was connected wirelessly to an I-phone which recorded the results. The acceleration of the arm was measured in the x,y and z planes in separate experiments. The results follow.

Table 2 - Condensed Accelerometer Experimentation Results J.Fogarty 2014

	Subject 1			Subject 2		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Time (s)	(X axis) (G)	(Y axis) (G)	(Z axis) (G)	(X axis) (G)	(Y axis) (G)	(Z axis) (G)

0	-0.01	-0.29	0	1.07	-0.37	-0.42
1	-0.01	-0.3	0	1.07	-0.37	-0.42
2	-0.01	-0.7	0.43	0.9	-0.48	-0.42
3	-0.07	-0.41	0.5	0.89	-0.35	-0.15
4	-0.26	-0.22	0.51	0.78	-0.09	-0.49
5	0.17	-0.71	0.52	0.93	-0.43	-0.98
6	-0.22	-1.07	0.66	0.89	-0.54	-0.31
7	-0.59	-0.73	0.82	1.15	-0.22	0.04
8	-0.64	-0.7	-0.28	0.88	-0.36	-0.47
9	-0.53	-0.7	1.01	1.09	-0.45	-0.21
10	-0.49	-0.78	0.11	1.35	-0.37	0
11	-0.35	-0.63	0.8	0.9	-0.29	-0.72
12	-0.58	0.34	0.99	1.02	-0.22	0.06
13	-0.55	-0.79	0.43	0.74	-0.42	0.18
14	-0.53	-0.63	1.04	0.83	-0.6	0.11
15	-0.54	-0.37	0.82	0.65	-0.21	0.11

Max acceleration achieved by subject 1:

$(-.28) + (1.01) = 1.29$ G in the positive z direction

Max acceleration achieved by subject 2:

$0 + (-.72) = 0.72$ G in the negative z direction

Note: sign of value refers to direction of acceleration

The second developed experiment determined the max acceleration which could be achieved by the arm of the subject. This was calculated by weighing the subjects arm and then seeing the max force that could be applied by the subjects arm to a weighing scales

Table 3 - Weighing Scales Experimentation Results J.Fogarty 2014

	Primary Subject	Secondary subject
Weight of arm (Kg)	4.6	3.7
Applied force of arm (Kg)	5.3	4
Max Acceleration of arm (M/s/s)	11.3028	10.6
Max acceleration of arm (G)	1.15	1.08

Conclusions from Preliminary Testing

As may be observed from the accelerometer testing, the greatest range of mobility for the subjects was in the Z axis - this range will be utilized in the music system. The subjects range falls within a ± 1.5 G range and the largest acceleration created by the primary subject was 1.29G. One may observe from the second set of experiments that similar results were obtained for the max acceleration. The max acceleration for the primary subject was 1.15 G and for the secondary subject was 1.08G. To ensure that each movement of the subject is recognised, a ± 3 G accelerometer is to be purchased. More extensive testing results given in Appendix A indicates that the subjects' movements were not exactly in the specified direction. The X and Y axis will be initially used in menu selection for different keys, sound effects and more expressive music.

Specifications of Components

Data Acquisition Module

The data acquisition module chosen is the national instruments USB-6000. This data acquisition module can easily be connected to a computer via universal serial bus and can be used with the software LabView. It is low cost (€ 144) and contains eight analogue inputs, with sufficient speed and resolution. Sensors are easily connected with screw terminal technology which reduces time attaching sensors. The selected module is of very small size and can be easily transported - important as experimentation will be carried out in different locations.



Figure 7 -USB 6009 DAQ Module

Accelerometer

The accelerometer chosen is the ADXL335 accelerometer from Analog devices. This accelerometer has a three axis sensing ability to allow for a wide variety of movements to be recognised and to give many options for potential gestures. The small size of the accelerometer means that it can be easily attached to the subject and it does not incur significant additional weight to the already restricted movement of the subject. The accelerometer runs on low power - allowing for a greater lifespan of the batteries. An accelerometer which requires a power source of only three volts (2 AA batteries) has been selected. This again reduces the overall weight and profile of the attachment. The accelerometer has very good temperature stability and will not be affected by the temperature of the body. Bandwidth can easily be adjusted with the addition of a single capacitor per axis this ensures aliasing is not an issue. The accelerometer gives a voltage output which is necessary for data acquisition.

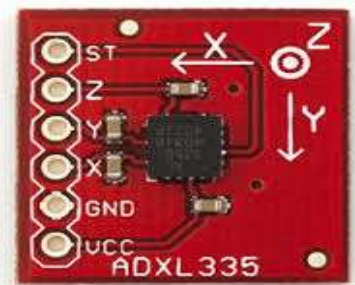


Figure 8 - ADXL335 Accelerometer

Prototype development

From the primary experimentation, it was apparent that the acceleration from the head and the arm could be used as a method of creating music. The first task was to solder the wires to the accelerometer. Multicore wires were used to allow flexibility and each wire was of a different colour to avoid confusion when allocating wires. The next task was to connect the accelerometer to the data acquisition module. The accelerometer specifications stated that it required a voltage of between 1.8volts to 3.6 volts. This was supplied by the data acquisition module which provides a 2.5 volt power supply to the accelerometer. The prototype utilised both head and hand movement to create sophisticated music with the available movements of the subject.



Figure 9 - Accelerometer Placement J.Fogarty 2014

Primary Accelerometer

The primary accelerometer is designed to utilise the movement of the hand - placed on the hand in a safe, comfortable and effective way. The accelerometer is protected from damage via a plastic housing. A strap system was developed to facilitate attachment to the subject.



Figure 10 - Primary Accelerometer J.Fogarty 2014

Secondary Accelerometer

The secondary accelerometer is designed to utilise head movement and therefore be placed on the head safely, comfortably and effectively. The head accelerometer is contained securely within a protective plastic housing and attached to the head via a sweatband.



Figure 11 - Secondary Accelerometer J.Fogarty 2014

LabView Design Evolution

The developed Lab-View programme had to achieve the difficult task of converting the acceleration from the accelerometer to corresponding notes through the speakers of the laptop. The first step in completing this task was to input the acceleration data into the LabView programme. This was completed via using the “DAQ assistant” which allows the user to measure and manipulate the relevant data. The accelerometer converts acceleration into voltage, which is acquired in the port selected. From previous experimentation, it was apparent that the z-axis is the best axis of movement. Therefore the values being read for the z-axis are crucial. Before any programming, it was important that the accelerometer be given correct corresponding values. Testing was undertaken in the “DAQ Assistant” and is illustrated in Figure 12.

Channel	Value
Voltage	-162.386522m
Voltage_0	-120.323539m
Voltage_1	-34.298225m

Figure 12 - Testing of Accelerometers J.Fogarty 2014

Initial Design

To use the voltage values in terms of creating music, it was important to convert the dynamic data type into a numeric array data type, so it would be much easier to manipulate. This conversion was carried out using a “convert from dynamic data type” module on the data being outputted from the “DAQ assistant” - as seen in Figure 13.

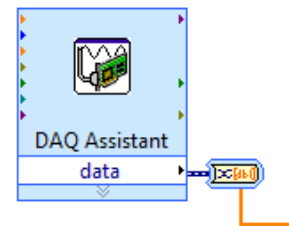


Figure 13 - Convert to Dynamic Data Type

Unfortunately, this data contains all the three signals from the accelerometer(x,y,z). Another operation is needed to receive the signal that is required from the z-axis - this operation is known as decimate 1D array, which places the single array into a succession of individual output array and is illustrated in Figure 14. The decimate 1D array breaks the signals up into the three successive signals as specified by the “DAQ assistant”.

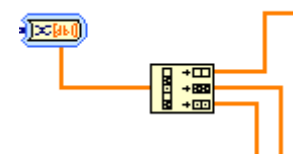


Figure 14-Decimate 1D array

A waveform chart is used to illustrate the data from each of these signals which was also used for validating the method of making music notes. In this system when the voltage is within a certain limit it activates the note. The voltage fell within these specified limits as illustrated in Figure 15.

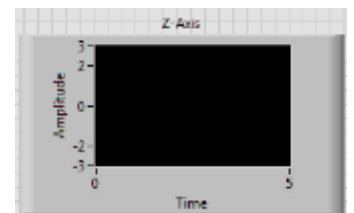


Figure 15-Waveform Graph

The optimum method for creating music with the acceleration was to use Boolean expressions of “greater than”, “less than” and the “and” function. When the voltage fell in the limits of less than a specified value and greater than a specified value, within the specified time

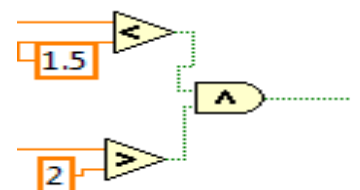


Figure 16-Boolean Expressions

frame it would create a “true” output. Otherwise the output would be “false”. This true value is used to activate a case structure and its contents, ensuring that a series of notes were not being played. The notes start at a range above zero - to ensure that no notes were being played when the accelerometer was not moving. These Boolean expressions can be seen in Figure 16.

The timing for each sample could be determined by using a timed structure loop. This contained all the operations within the while loop and their timing and can be seen in Figure 17. **Figure**

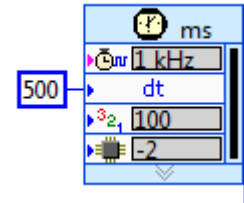


Figure 17 -Timed Structure Controls

The case structure contains the options of true and false. For this it was important that the case structure did not cause problems when in the “false” mode. When activated the case structure utilised a “Beep VI” which causes the system to create an audible tone. The VI refers to a virtual instrument within LabView. The frequency of the tone (Hz) is inputted into the first channel. The second channel controls the length of the tone (ms). This can be seen in Figure 18. This virtual instrument is designed to create alerts and outputs beeps at the designated frequencies through the speakers. Eight notes with frequencies in the scale of D were used to form the original music creation system.

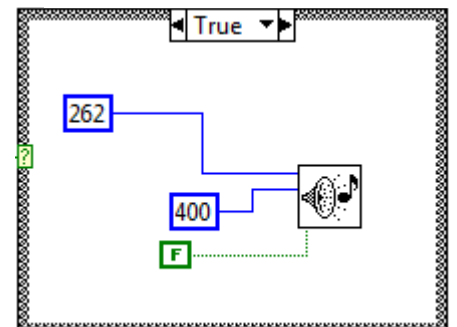


Figure 18-Case Structure containing BeepVI

Improvements

Playing Sound Files

Unfortunately utilisation of the “Beep.VI” would only create tones rather than notes. However the system of using the case structures to create sounds was sufficient in executing accurate notes in response to acceleration. Therefore a method of creating actual notes was developed using the “Soundfilesimpleread.VI”.

This VI automatically opens, reads and closes the .wav file. The .wav file is an audio file format which can be used in LabView. A path was added to the “Soundfilesimpleread.VI” which specifies the path of the .wav file. The last step was to play the sound file via a play waveform module which plays data from a sound output device. The task is cleared after the output is complete. This is important so that the note can be played more than once. The method of playing sound files is illustrated in Figure 19.

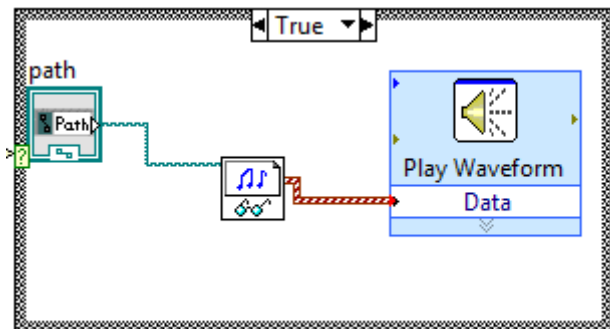


Figure 19-Playing Sound Files

Visual Display of Notes

This project aims to be a learning experience for the student the same as any other instrument. The method of doing this is to display the notes on screen for the student to see. From the case structure a “string constant” is used to visually display a letter or word associated with the true or false state of the Boolean expression. In this case the note was displayed visually with the note audibly. From Figure 20, it can be seen that when the note C is played it will be visually represented in the front panel. Likewise if the C is not played, nothing will be displayed.

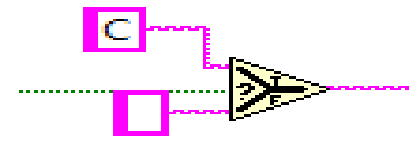


Figure 20- True and false selection

This can be set up with a string indicator for each instance; however it is much better to have one display in which all the notes will appear. This is completed via using a concentrated string to join all the displays together this can be seen in Figure 21. This works because only one case structure can be true at any one time and therefore only one note will be displayed at any one time and can be displayed in one indicator.

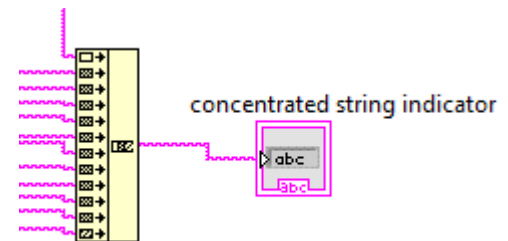


Figure 21 -Concentrated String

Using Different Sets of Sound Effects

Using different sets of sound effects is important because this is something in which is standard for the other adaptive music technologies. The best method of achieving this is to use case structures to surround the selection of music sounds to be created. The case structure is then activated by using a Boolean control. Only one case structure should be activated at any time. The set of sounds selected consisted originally of piano and guitar sounds. The Boolean expression can be seen in Figure 22.

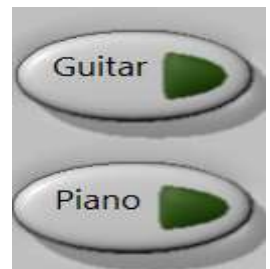


Figure 22-Boolean Controls

Creating Sound Files

Using the .wav files the length of the notes could only be controlled within the file itself. The sound file had to be created using the Ableton digital audio workspace (DAW). The desired notes lasted a second in length. The first step was to select the correct sound for the note. The desired sound was the clean guitar which was subsequently selected is illustrated in Figure 23.

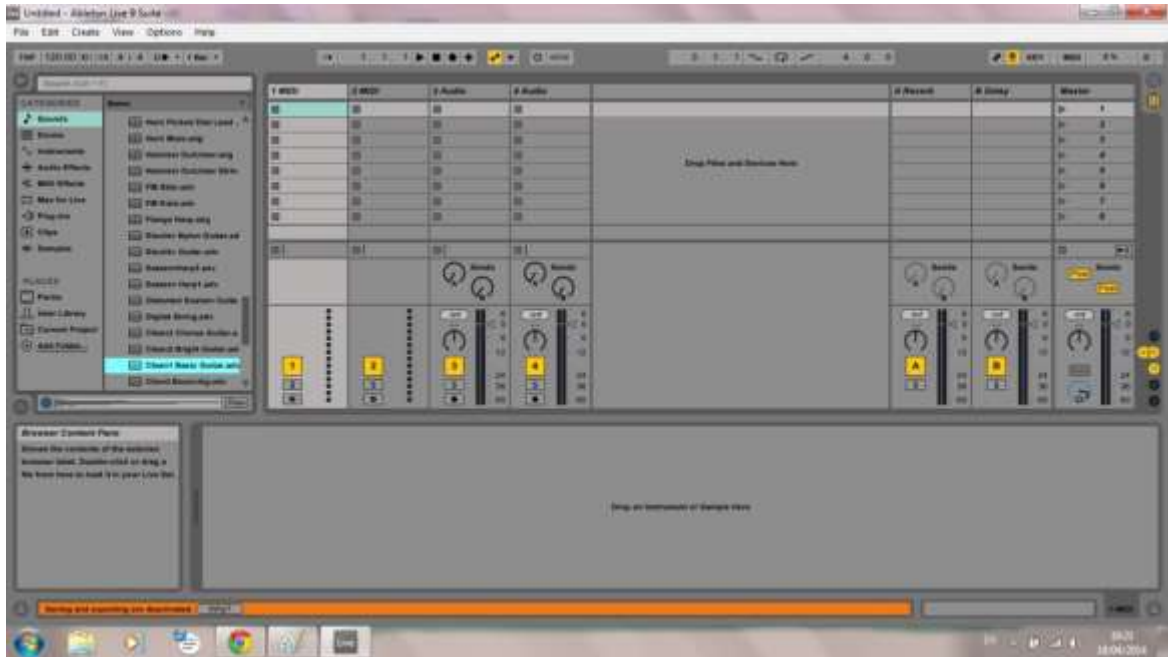


Figure 23 - Selecting Sound on Ableton DAW J.Fogarty 2014

With this sound selected the next step was to select a scale and a note (the D scale was selected and D3 to start). A second of this note was recorded. The length of this note was selected as one second for the prototype. This can be seen in Figure 24. The D-scale was chosen because it is a scale commonly used, especially with Irish music.

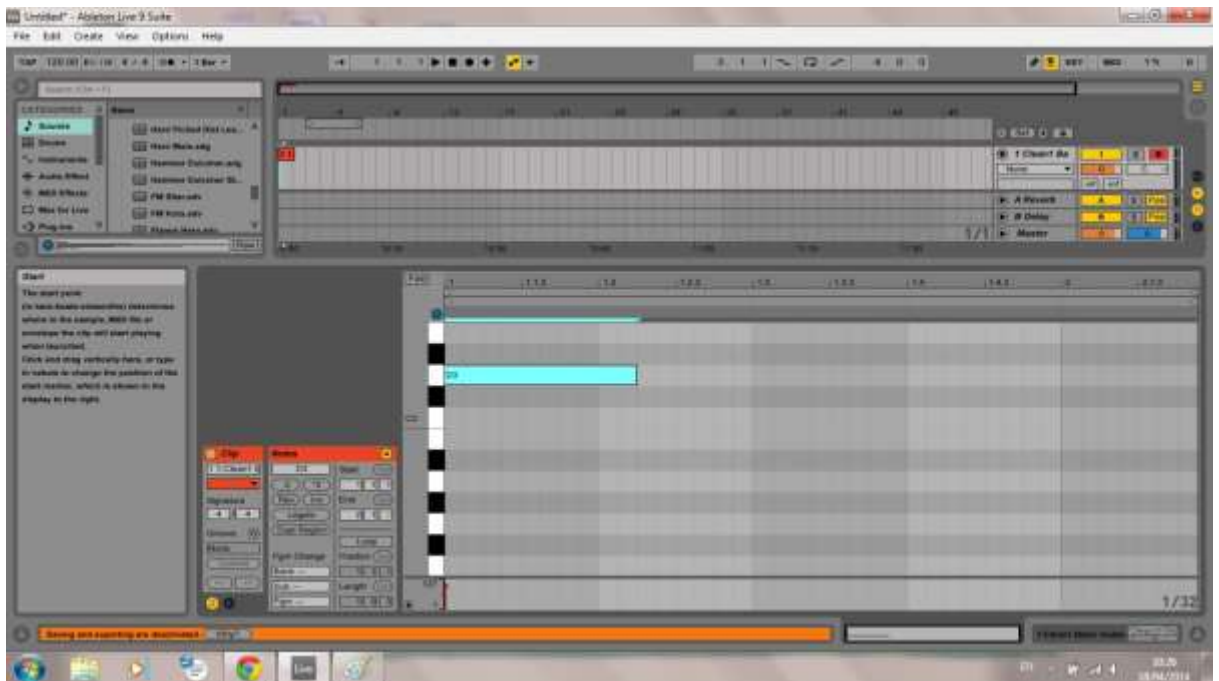


Figure 24 - Determining Note and Length Using Ableton Software J.Fogarty 2014

Labview can only read the .wav file type which can be exported from Ableton as is illustrated in Figure 25. A separate .wav file was created for each note guitar required in

the program. The same process was used to create the piano notes and drum sound effects.

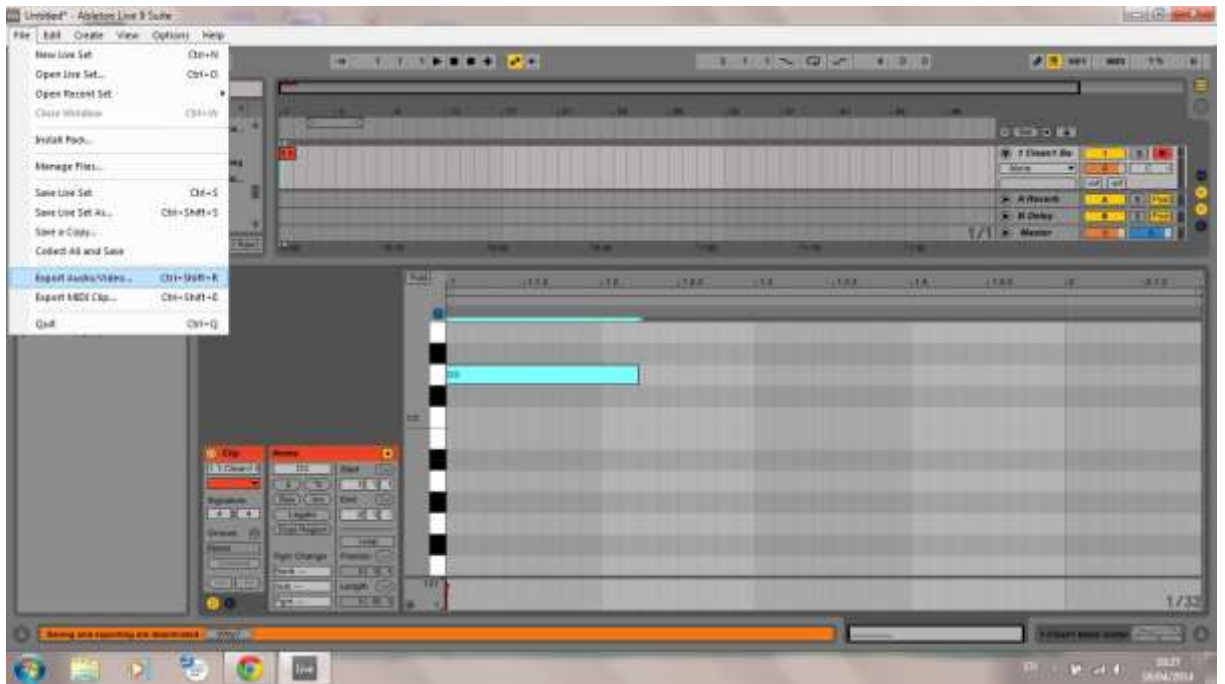


Figure 25 -Export Audio File in Ableton J.Fogarty 2014

Playing Background Music within the Programme

An improvement to the software is to allow the subject to play along to a specified sound file. Allowing the background music to come from the same sound source as the created music gives the impression that the music created is complimenting the original music. It allows the subject to practise timing and learn how to use the prototype more effectively. This was created firstly by specifying the file path which has to be a .wav

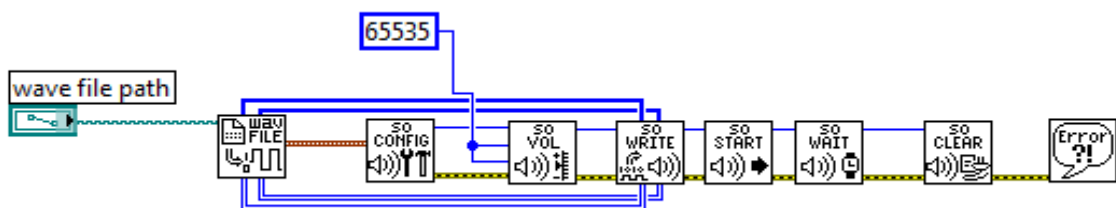


Figure 26 -Playing Background Music J.Fogarty 2014

file. The connecting VI is known as the “second read wav file.VI” which in essence retrieves the wav file. This is connected to the “SO Config. Vi” which configures the sound output device. The volume of the file is controlled via the “So Volume Vi”, which has a minimum volume of zero and a maximum volume of 65535. By changing the connected control the volume can be changed within these limits. The “So Write Vi” is used to write data to the sound output device. The “So start Vi” is to start the

sound file associated with the input parameter. The next step is to wait until the sound output data has finished playing all the data it has received, this is controlled with the “So Wait Vi”. The “So Clear” data is used to close the file when it has finished. The “Simple Error Handler” indicates if an error has occurred. This can be seen in Figure 26.

Application of Dual Accelerometer System

Using two accelerometers involved manipulating two different channels at the same time. This was completed via using two separate case structures per accelerometer. The required channel was manipulated similar to using the first accelerometer. The system of activating case structures corresponding to the acceleration was utilised in co-ordination with the hand accelerometer. For the two accelerometers to work simultaneously the operation of the “DAQ Assistant” had to be altered to give samples on demand. The timing for these samples to be taken was given by using the “millisecond to wait” module to control which in essence demanded when these samples could be taken, this was connected to a control which could be changed in the front panel to optimise the system - seen in Figure 27.



Figure 27 -Sample on Demand Timing

The sensitivity had to be controlled for the head and the hand accelerometer. This was done using a basic multiplication command which multiplied the value being outputted from the accelerometer which can be seen in Figure 28.

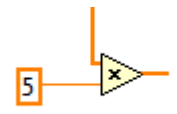


Figure 28-Basic Multiplication

The head accelerometer was configured to be twice as sensitive as the hand accelerometer due to the greater accelerations which can be reached with the hand. An offset occurs when using the accelerometer which causes problems with making music as the accelerations are in-accurate. To deal with this issue an offset was used to get of rid of this change - this can be seen in Figure 29. However the offset constantly changed therefore this problem was re-occurring. A calibration Vi was developed to control these errors.

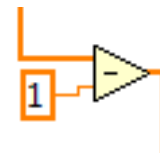


Figure 29-Basic Subtraction

Calibration

The calibration of the accelerometer aimed to use an averaged value for the voltage being received for the accelerometer to remove the offset. The offset constantly changes so to combat this the calibration should commence every time the system is used. The calibration would have to be implemented in the original programme for creating music. This is completed via using a “SubVI” which is a Vi inside in a Vi. The “DAQ assistant” has to be used to implement the two relevant voltages (head and hand acceleration). Figure 30 shows the block diagram of the calibration SubVI.

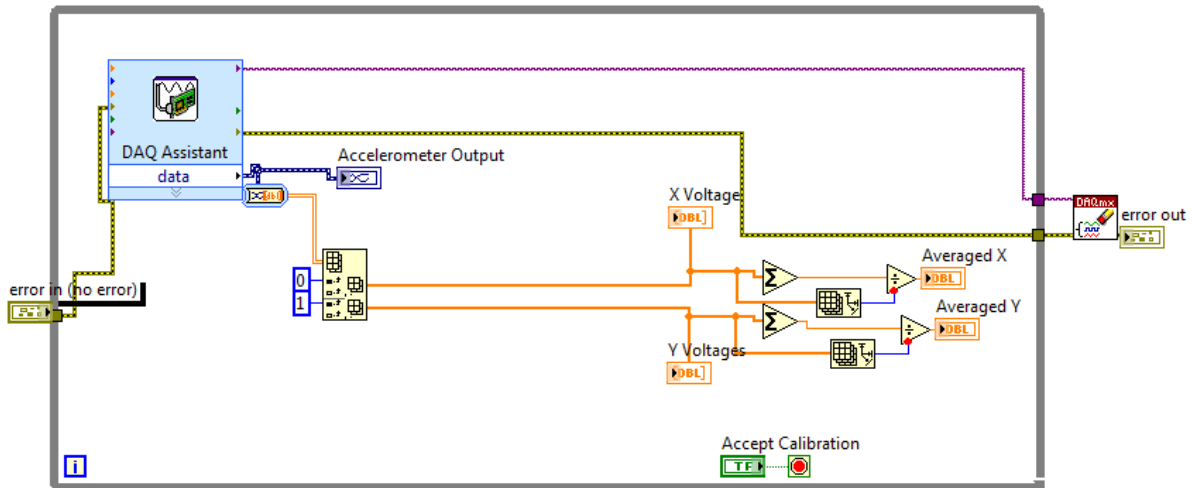


Figure 30 - Calibration SubVi Front Panel J.Fogarty 2014

When dealing with VIs corresponding with one another the error incurred is very import and certain controls have to be in place to make sure to show issues or bypass functionality if there is a problem. This is connected to the input and the output of the “DAQ Assistant”. This functionality is illustrated in Figure 31.

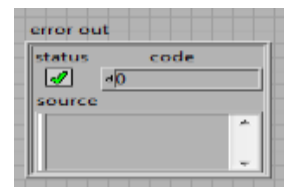


Figure 31-Error out

To understand the calibration sequence and to visually inspect any problems which may occur, a graph to represent both voltages was introduced into the calibration programme. An index array was used to break up the signal into the two components to allow the signals to be manipulated. This can be seen in Figure 32.

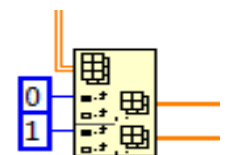


Figure 32-Index array

To get the average of all the voltage values for the head and hand accelerometer, it involved using an add array elements to make a sum of all the voltages and then divide by the number of samples after being taken. The number of samples is determined by using the array size block. The dividing is completed via the divide command. This combination can be seen in Figure 33. A thousand samples are taken a second, therefore the averaged value will be very accurate.

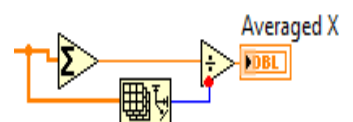


Figure 33-Obtaining an Average Voltage Value

The clear task option is used in this SubVI to keep any resources necessary to the SubVI but ensures no data is constantly saved

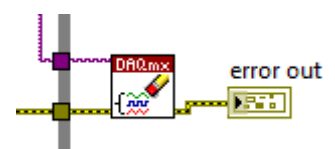


Figure 34-Clear Task

within the VI. This is important so that every time the original programme starts up the calibration will restart also. This can be seen in Figure 34.

These averaged values have to become an output for this this Vi. On the front panel right click on the VI icon (top right hand corner) and then click "edit connector". LabVIEW automatically assigns the number of "boxes" in the connector to the total number of controls/indicators on your front panel. Similarly the icon which represents this VI can be easily be altered so this SubVI can be easily determined in another VI. To input the created SubVI into another VI is simply by the select a VI option. Figure 35 shows the modulated calibration VI as it is represented in the music making Vi. The averaged accelerations can be removed from the used accelerations by using the minus command. The reason for using the minus command is to remove the offset. If the offset is a negative value it will be added because of the double negative (minus command), similarly if the offset is positive it will be deducted. Therefore the offset value is removed and a zero baseline is achieved.

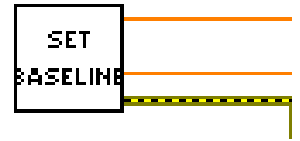


Figure 35 - Calibration SubVI

To complete the calibration the subject has to keep the accelerometer from moving for a few seconds. The large sampling rate ensures good accuracy. When the programme is running the calibration starts up automatically, the movement can be seen on the graph and the calibration can be stopped by clicking the accept calibration button. This can be seen on Figure 36.

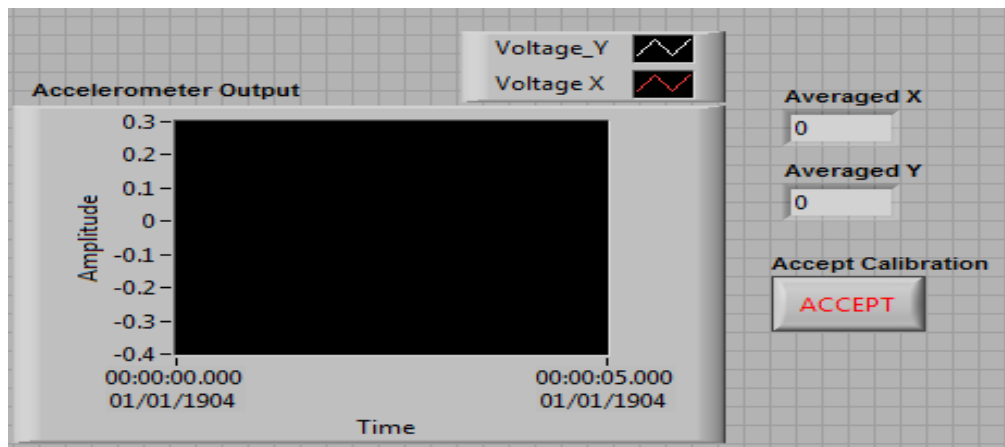


Figure 36 - Calibration Front Panel J.Fogarty 2014

Application Creation from LabView

The software created has to be compatible with all computers. To achieve this compatibility, an executable file is built which would not need LabView to run. Therefore, it would incur much less of a cost to the customer and save installation time. When building the application it is crucial that all SubVIs are implemented and the data acquisition device information is also a part of the execution file. The execution file does not require an application to run the file. It is itself an application. From the executable file an installer can be created so that the file can be installed on a different computer.

When an application is built only the front panel can be accessed therefore it is very important to be user friendly and self-explanatory. Figure 37 shows the developed front panel for the music making application. By pressing the guitar button the guitar sounds are activated whilst by pressing the piano button the piano sounds are activated.

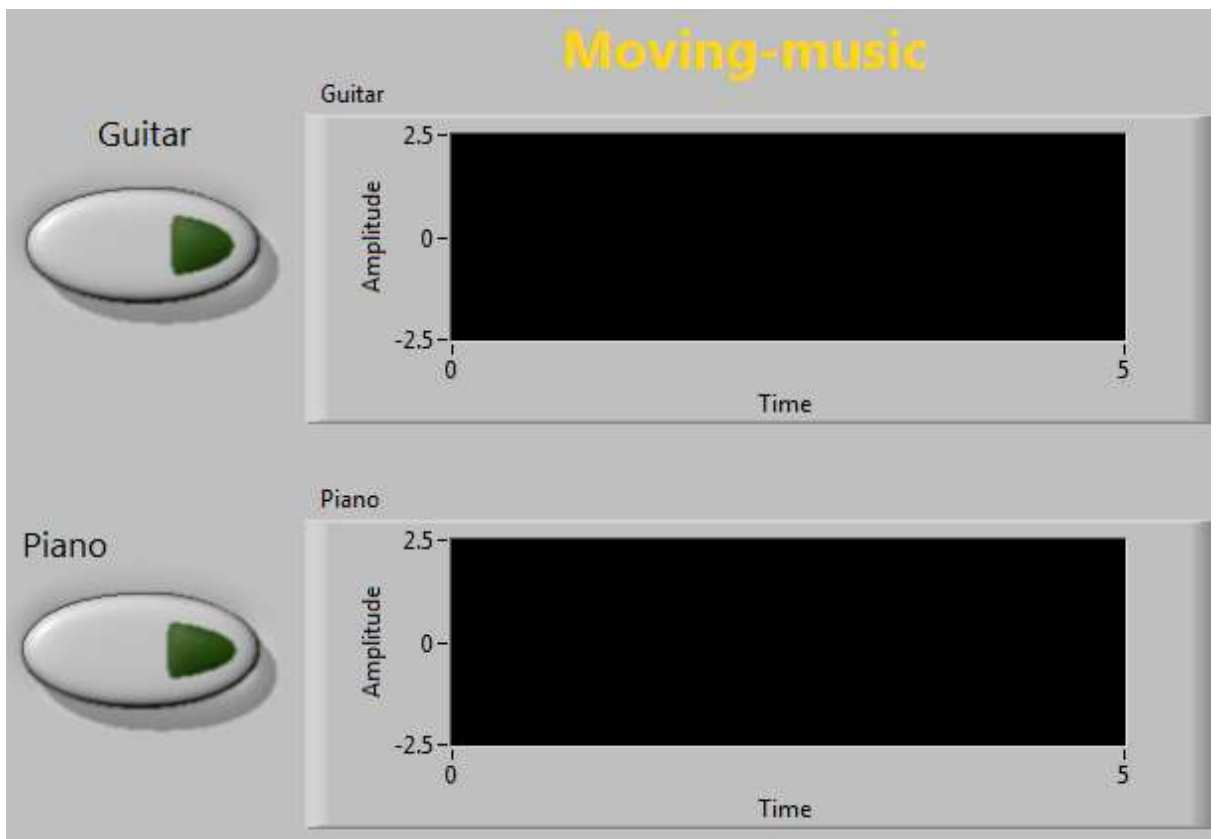


Figure 37 - Developed Front Panel J.Fogarty 2014

Recording Experimentation Results

To validate the systems effectiveness and to optimise the system in correspondence with the customers' demands, the data received had to be recorded and analysed. This was completed via utilising the "write to measurement file" which can be seen in Figure 38. This records the data

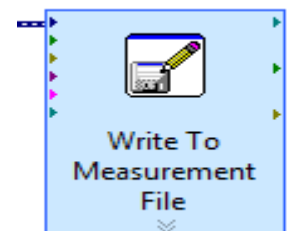


Figure 38 - Write to measurement file

and places in a file saved as a LabView Measurement file. This can be converted using Microsoft excel.

Validation Testing

Primary Validation Testing

A series of tests were developed to evaluate the ability of the system to create music with the available movements of the subject. The results were used to remove any bugs or glitches in the LabView system. The results were recorded using a write to measurement file command in LabView.

Test 1 was conducted with just the arm movement to determine the effectiveness of the 1st accelerometer and the range of accelerations which could be achieved. The results are shown in Figure 39.

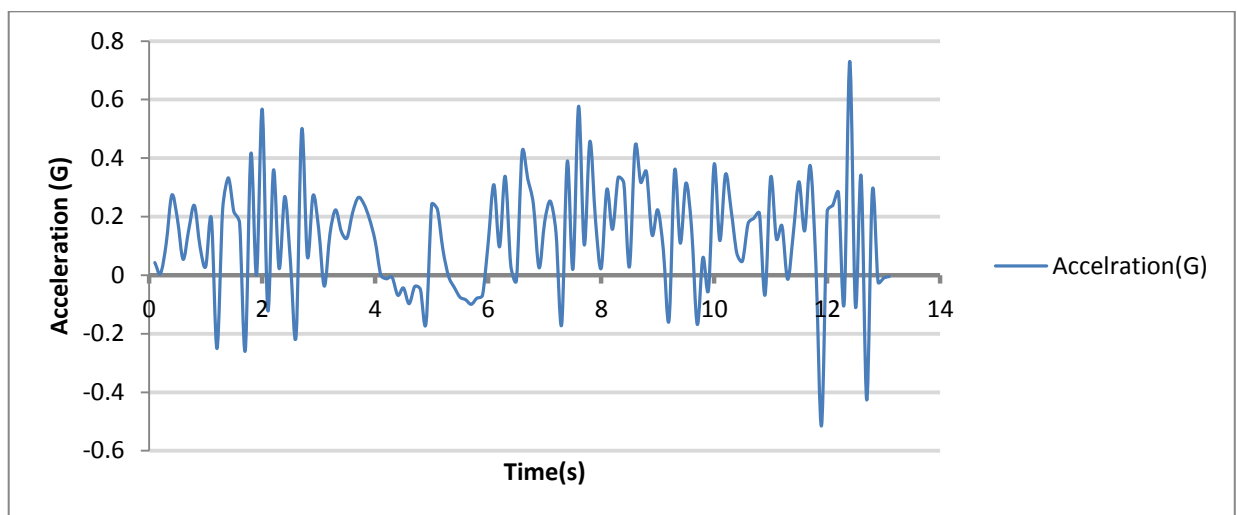


Figure 39 - Acceleration of the Arm in the Z direction in Initial Testing J.Fogarty 2014

Test 2 was conducted with just head movement to determine the effectiveness of the second accelerometer and the range of accelerations which could be achieved. The results can be seen in Figure 40.

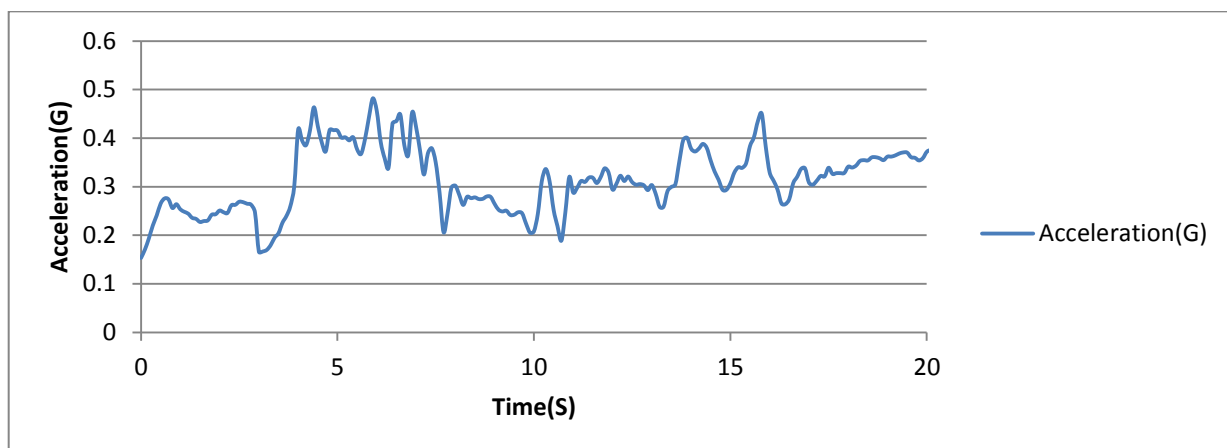


Figure 40 - Acceleration of the Head in the Y-axis in Initial Testing J.Fogarty 2014

Test 3 is to test the percussion programme using both head and arm movements with percussion sounds. This can be seen in Figure 41.

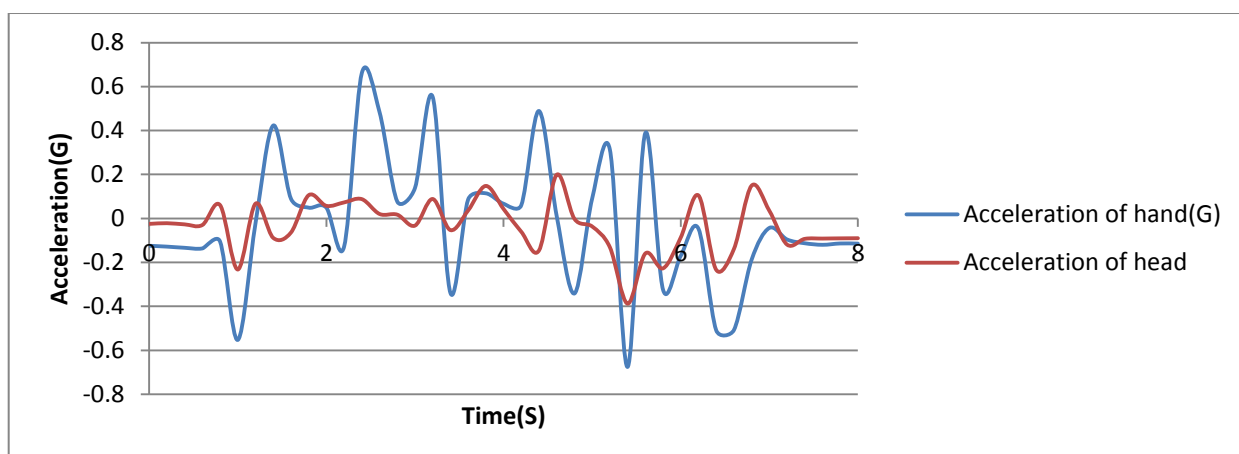


Figure 41 - Acceleration of the Arm and Head Simultaneously in Initial Testing J.Fogarty 2014

Conclusions from Preliminary Validation Testing

1. An offset option is required to calibrate the system before use. (both accelerometers).
2. An increase in sensitivity of the LabView system is required.
3. Head movement should be in the forward direction - this is much easier for the subject. Therefore change use of axis from y-axis to z-axis.
4. Co-ordination of head and arm is achievable - however there are issues with timing.
5. Accelerometer should be held more securely within the designed housing to prevent unwanted accelerations.

Secondary Validation Testing

After preliminary validation experimentation, the necessary changes were made to the software and the hardware and a similar set of tests were conducted - however this time a programme was developed which allowed the subject to play along to the music.

Test 1 was conducted with arm movement playing the notes requested by the corresponding acceleration. The results can be seen in Figure 42.

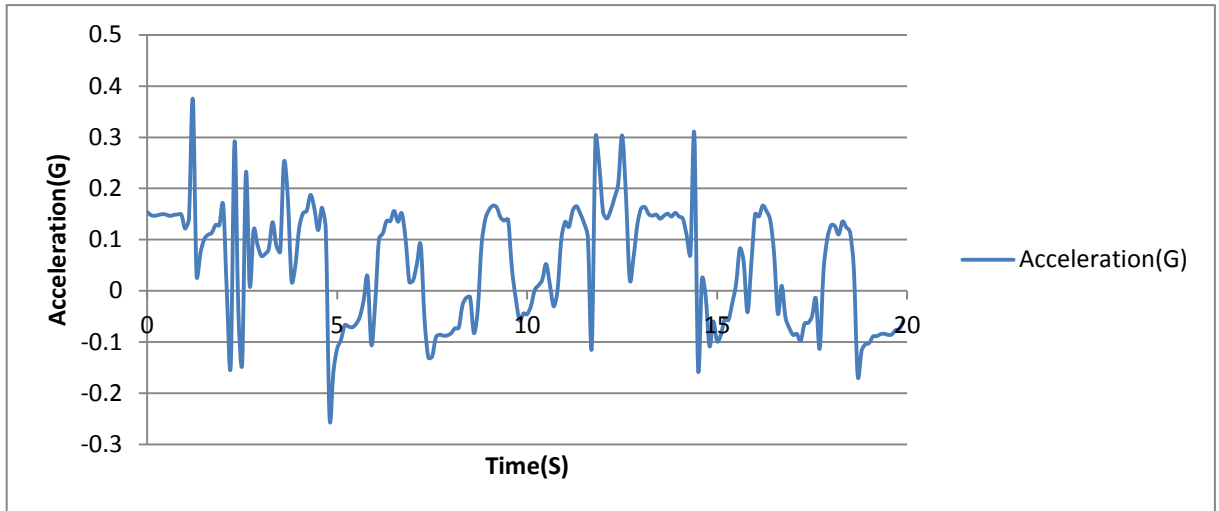


Figure 42 - Secondary Testing of Hand Acceleration J.Fogarty 2014

Test 2 utilised the head movements of the subject to determine if the change in axis would be of benefit to the range of acceleration. The range of acceleration can be seen in Figure 43.

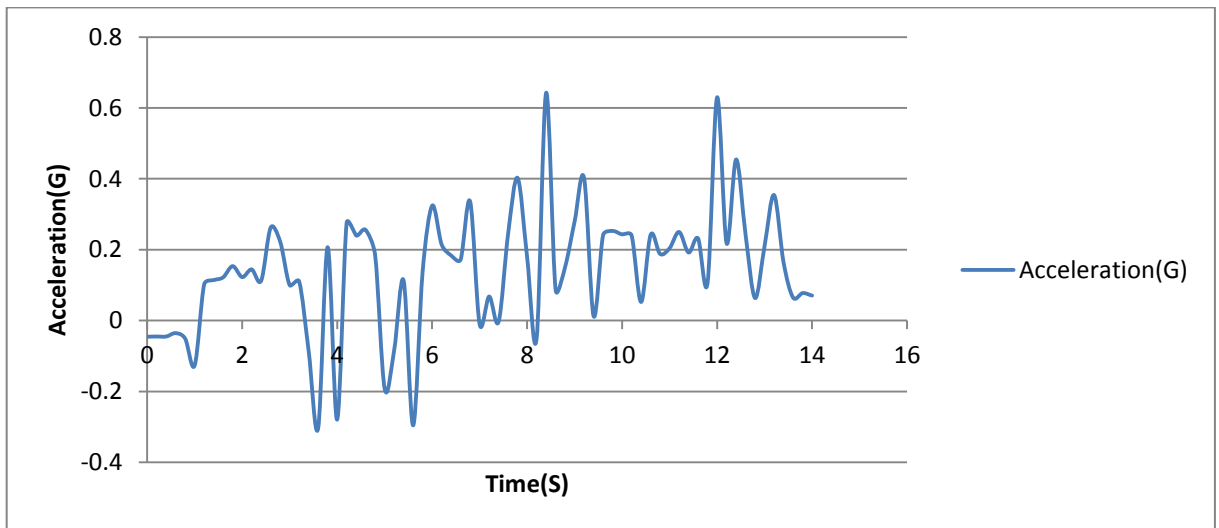


Figure 43- Secondary Testing of Head Acceleration J.Fogarty 2014

Test 3 utilises both head and hand accelerations to create percussion alongside a pre-selected song. The aim for the subject would be to complete sounds at certain times appropriate to the song.

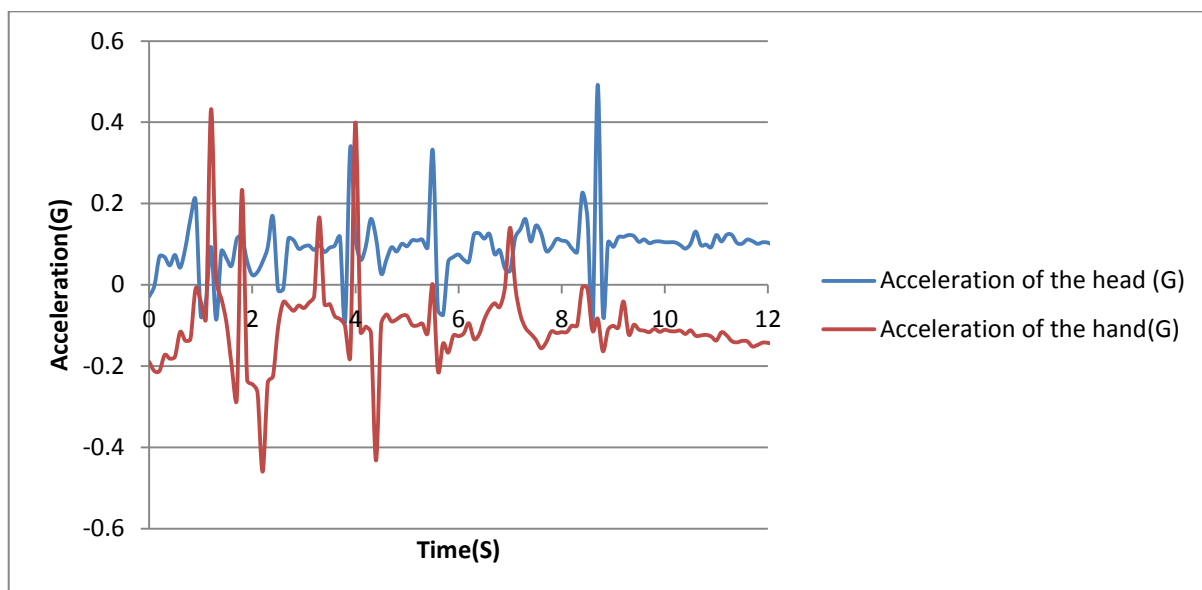


Figure 44 - Secondary Testing of Prototype with Music J.Fogarty 2014

We can see from these results in Figure 44 that the subject has control of the timing of the sound effects. On four seconds both the head and hand accelerometer are being utilised simultaneously to make sound effects which shows good co-ordination and timing.

Conclusions from Secondary Testing

1. Shortening the response time, improving sensitivity and using an offset have allowed sophisticated music to be created with simple gestures.
2. The subject has greatest control of head acceleration in the positive z-axis. The programme will be altered slightly to ensure optimisation of this acceleration. The sensitivity should also be slightly altered.
3. With these improvements and with the addition of an auxiliary cable, the music can be connected to a PA system and be played with other musicians in real time.
4. A slight problem still exists in relation to the offset because it has a tendency to change, which is the nature of an accelerometer. To deal with this issue, a calibration VI will be utilised.

Adaptability

The subject has the ability to use buttons with the left hand. This could be utilised to start and stop the music making device to make it more accessible for the subject to use the device without the need of the system to be set-up by the care-assistant. The subject could start and stop the process as they see fit. The button would not be used as a method of making music because it would make the system more confusing to operate and wouldn't give the "feel" of an instrument.

The prototype is currently configured to aid a person with cerebral palsy to play music. With further experimentation it would be possible to alter the programme so it can utilise weaker or stronger movements. Similarly if the person's range of motion was greater in another direction, the axis could be easily changed.

Therefore it would be possible to convert the movements of a range of other disabilities by simply changing the programme. Possibly stroke victims or muscular dystrophy subjects could avail of these alterations.

The 3-axis accelerometers can also be programmed to act similar to a gyroscope (measure orientation). This could be utilised to help very weak subjects to create music effectively.

Another way in which the system could be used is with a more mainstream approach. Electronic music technology is constantly improving and the system could be utilised not only for music creation but for music modulation. If LabView was co-ordinated with software such as Ableton, then using the software could be more assessable and enjoyable experience.

Altering and creating music in a unique and innovative way would be very appealing to people with physical disabilities and also could appeal to the general public.

Music-ability™ Product Business Potential

The project is at the hand-over stage - therefore it is appropriate to analyse the business potential of the product. The prototype has been successfully calibrated and tested with the subject.

Prototype Cost

A detailed materials breakdown costing of the developed and manufactured prototype is undertaken and is presented in Table 4. Software costs have been negated by the development of a stand alone dedicated Music-ability™ app by the author.

Table 4 - Cost of Music-ability™ Prototype Components J.Fogarty 2014

Cost of Music-ability™ Prototype Components
Accelerometers (2) - €20
DAQ module - €100
Headband and Wristband - €10
Connectivity Cabling - €5
Software – Stand Alone Author Developed App - €0
Total - €135

It must be emphasised that the material costs presented are based on once-off prototype production and will be significantly reduced due to economies of scale and efficiencies of mass manufacture on product production for market.

Customers

Customer satisfaction is very important with this product. This product addresses a niche market, sufferers of cerebral palsy, not adequately addressed by competitors. These people are very limited in their daily lives and music is their chance to express themselves. Music is a great way to bring people together and for them to enjoy themselves. This product allows the subjects to perform at a much more sophisticated level and have their music easily recorded at the touch of a button. This product was originally aimed at people with cerebral palsy - however with some further software development, it can be easily programmed to a range of other physical disabilities.

Unique Selling point

The developed enablement product Music-ability™ has a most significant competitive edge on its competitors. It provides the user with the “feel” of a musical instrument and can bring musicians with and without disabilities together to record music and play music live. The main advantage that this project has over its competitors is its adaptability. Adaptive music technologies can be very general and there is a lot of problems when the subject cannot use the equipment properly, causing significant frustration for the subject. The Music-ability™ product can be adapted to cater for a wide range of disabilities. Accuracy is another big advantage - project notes can be skipped and with practice can be picked accordingly. Every musical scale can be easily picked and notes from the corresponding scale played. The product size makes it much easier to carry around than other forms of music creation and no stands have to be set up.

Conclusions

- The arm and head movement of the subject has been assessed and characterised. From the testing, the forward and back movement of the head and the up and down movement of the arm contains the greatest range of acceleration. Therefore the z-axis can be utilised in both accelerometers.
- Extensive research was completed to analyse all aspects of current music technology and viable methods available to address the system of music creation. From the research, it was concluded that there is a niche market available for a musical system which has not been addressed by current adaptive music technologies.
- The optimal system of creating music was decided upon using a systematic design approach. This design utilizes a dual three-axis accelerometer and data acquisition module system processed through the LabView platform to create more sophisticated music that is possible with current systems.
- The concept has been proven using basic beeps which correspond to specific voltages created by the accelerometer using the LabView software.
- From this original concept, a programme was designed to achieve the eight basic notes in a scale using simple movements of the arm.
- A second programme was developed which utilises both the head and hand movements to create corresponding percussion sound effects.
- Both programmes were improved and optimised to aid the creation of music with additional features such as different sound effects, calibration and displaying notes.
- The music creation system can be connected to a public address (PA) system to play with other musicians live and to record music. This connectivity is achieved via an auxiliary cable and an auxiliary cable jack.
- The programme was tested with the subject and alterations to the software were completed to enhance the music creation capability of the subject and ensure consistent performance.
- The project is at the hand-over stage. (See Figure 45)
- A comprehensive illustrated operating procedure was completed. (See Appendix B)
- The marketability and scope of the project have been assessed.
- The subject is satisfied with the operation of the device and the simplicity of the controls to create sophisticated music. The Sound-out organisation are satisfied that the project has achieved its desired objectives.

Handover of Music-ability™ Prototype



Figure 45 - Handover of Music-ability™ Prototype
(Photo reproduced with most kind permission of Christine and Parents)

The formal handover of the Music-ability™ Prototype to Christine, her parents and the SoundOut organisation took place on Monday 12th May 2014.

Future Work

- Investigation of incorporation of one axis accelerometers to reduce product cost. However using a one-axis accelerometer would not allow any future improvements to be made to the software to utilise other movements and also reduces the adaptability of the prototype.
- Music is something that should be shared easily and collaborating with software such as garage-band would allow this. The prototype allows for the recording of music which can be transferred into garage-band; however this process could be optimised to seamless transfer.
- Optimisation of the prototype to more seamlessly create music from a digital audio workspace such as Ableton.
- This project used wired accelerometers as utilisation of wireless accelerometers was deemed unnecessary to the functionality of the prototype. The incorporation of wireless accelerometers would make the prototype more aesthetically pleasing and attractive to the user.
- Incorporation of additional sound effects using both accelerometers. For example, the hand accelerometer could be used to pick the chord whilst the head accelerometer could be used to select the sound effect. From experimentation on head and hand movement, it was apparent that this particular subject had some difficulty in co-ordinating head and hand movement. However, if this prototype was used on a different subject, then this may then become a viable option.
- Investigation of the use smart phones to create music. Accelerometers are fitted in modern smartphones and an application could be created on the phone to create music using the accelerometer. The smartphone could relay the acceleration information to a data acquisition module or process the data internally. The music created could be easily shared on applications like garage band where it could be recorded or played live.
- Continued Liaison with Christine, and SoundOut Organisation.

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Appendix A

Sample Experimental Data

When collecting data from this experimentation it is important to note that acceleration wasn't just created in the specified direction. This is something that will have to be taken into consideration in the final design to ensure there are no inaccuracies and also to ensure that the subject doesn't accidentally select something whilst trying to play music.

Subject 1 X-axis experimentation

Time (s)	Acceleration: X (g)	Acceleration: Z (g)	Acceleration: Y (g)
0	-0.01	0.57	0.69
1	-0.01	0.57	0.69
2	-0.01	0.58	0.68
3	-0.07	0.66	0.63
4	-0.26	0.72	0.58
5	0.17	0.93	0.42
6	-0.22	0.84	0.34
7	-0.59	0.73	0.31
8	-0.64	0.8	0.03
9	-0.53	0.69	0.27
10	-0.49	0.66	0.33
11	-0.35	0.71	0.37
12	-0.58	0.74	0.45
13	-0.55	0.68	0.18
14	-0.53	0.66	0.3
15	-0.54	0.72	0.4

Subject 1 Y-axis experimentation

Time (s)	Acceleration: Y (g)	Acceleration: Z (g)	Acceleration: X (g)
0	-0.29	0.34	0.91
1	-0.3	0.34	0.91
2	-0.7	0.57	0.52
3	-0.41	0.46	0.85
4	-0.22	0.27	1.02
5	-0.71	0.21	0.8
6	-1.07	0.11	0.38
7	-0.73	0.32	0.72
8	-0.7	0.34	0.64
9	-0.7	0	-0.75
10	-0.78	0.84	-0.27
11	-0.63	0.69	0.36
12	0.34	0.66	0.33
13	-0.79	0.55	0.24
14	-0.63	0.48	-0.51
15	-0.37	0.44	0.98

Subject 1 Z-axis experimentation

Time (s)	Acceleration: Z (g)	Acceleration: X (g)	Acceleration: Y (g)
0	0	-0.62	-0.7
1	0	-0.62	-0.7
2	0.43	-0.74	-0.24
3	0.5	0.34	-0.58
4	0.51	0.41	-0.7

Design and Development of an Assistive Technology Music System for Sufferers of Cerebral Palsy

5	0.52	0.36	-0.49
6	0.66	-0.02	-0.47
7	0.82	-0.09	0.83
8	-0.28	0.12	-1.1
9	1.01	-0.06	0.37
10	0.11	0.09	-0.92
11	0.8	-0.03	-0.53
12	0.99	-0.21	0.5
13	0.43	0.24	-0.82
14	1.04	-0.32	0.76
15	0.82	-0.04	-0.39

Subject 2 X-axis

Time (s)	Acceleration: X (g)	Acceleration: Y (g)	Acceleration: Z (g)
0	1.07	0.14	-0.09
1	1.07	0.14	-0.09
2	0.9	0.19	-0.31
3	0.89	-0.13	-0.38
4	0.78	-0.09	0.01
5	0.93	0.01	-0.16
6	0.89	-0.02	-0.08
7	1.15	-0.14	-0.26
8	0.88	-0.01	0.22
9	1.09	0.24	-0.18
10	1.35	0.06	-0.53

Design and Development of an Assistive Technology Music System for Sufferers of Cerebral Palsy

11	0.9	-0.18	-0.29
12	1.02	-0.27	-0.33
13	0.74	0.11	-0.21
14	0.83	0.21	-0.42
15	0.65	0.67	-0.55

Subject 2 – Y axis

Time (s)	Acceleration: Y (g)	Acceleration: Z (g)	Acceleration: X (g)
0	-0.37	0.89	0.26
1	-0.37	0.89	0.26
2	-0.48	0.87	0.3
3	-0.35	0.86	0.34
4	-0.09	0.45	1.05
5	-0.43	0.68	0.75
6	-0.54	0.75	0.53
7	-0.22	0.47	1.18
8	-0.36	0.82	0.33
9	-0.45	0.89	0.3
10	-0.37	0.86	0.44
11	-0.29	0.86	0.13
12	-0.22	0.83	0.39
13	-0.42	0.88	0.36
14	-0.6	0.76	0.43
15	-0.21	0.84	0.38

Subject 2 – Z axis

Time (s)	Acceleration: Z (g)	Acceleration: Y (g)	Acceleration: X (g)
0	-0.42	-0.35	0.93
1	-0.42	-0.35	0.93
2	-0.42	-0.72	0.53
3	-0.15	-0.96	0.31
4	-0.49	-0.82	0.35
5	-0.98	-0.71	0.3
6	-0.31	-0.5	0.87
7	0.04	-0.92	0.08
8	-0.47	-0.45	0.63
9	-0.21	-0.76	0.68
10	0	-0.94	0.24
11	-0.72	-0.74	0.4
12	0.06	-0.81	0.98
13	0.18	-0.83	0.22
14	0.11	-0.83	0.48
15	0.11	-0.9	0.03

Appendix B

Operating Procedure for Developed Enablement Music System

Purpose

This operating procedure guides the user in how to install, calibrate and use the music making device effectively. It is required to ensure that no problems exist or arise when using the software and hardware. It allows the care-taker to become familiar with the operation.

Introduction

This device utilises two accelerometers and converts the motion into musical notes. The accelerometers have to be placed on the arm and the head. The device contains a wrist strap and a sweatband so that these can be attached to the subject. Two programmes have been developed. The first one uses just the arm movement of the subject to move up and down the D scale. The faster the movement upwards the higher the note similarly moving downwards moves down the scale. The second programme uses percussion sound effects and utilises both accelerometers. The arm movement controls high hats and symbols and the head movement controls base and kick drums.

Scope

This instrument is designed to be used by sufferers of cerebral palsy to utilise the movements available to create music expressively. This instrument is electronic and is implemented by simple movements.

Definitions

Calibration is a comparison between measurements. In this instance it removes the errors from the accelerometer to allow more accurate measurements and gesture recognition.

Procedure

Installation

1. To install the executable file to the computer double click the corresponding setup.exe file.
2. Select where the executable file is to be saved.
3. Click Next.

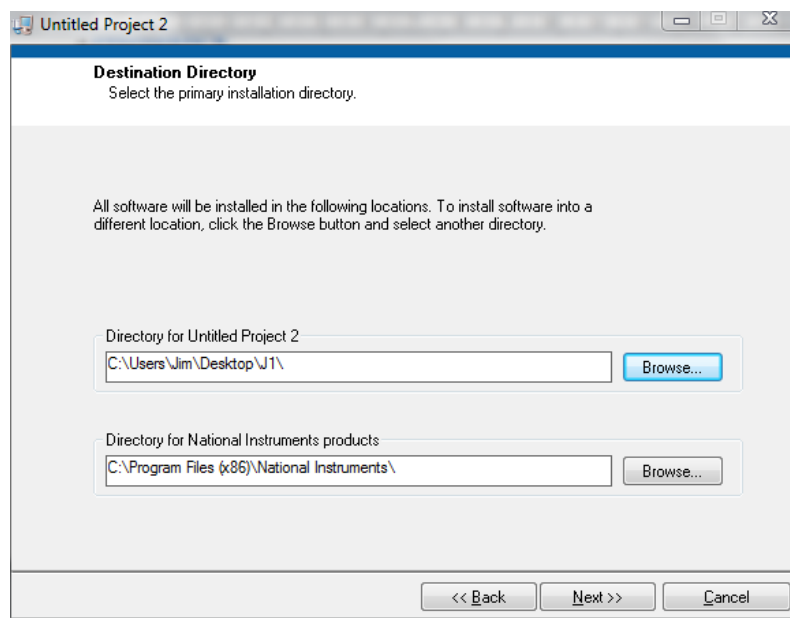


Figure B1 -Saving executable file

4. Click finish, it may take a few seconds for the programme to install. When completed the executable can now be used on the new computer.

Device set-up

1. Connect the cable to the data acquisition module and the USB slot in the computer.
2. Wait for the computer to recognise the device
3. Place the device the sweatband on the subject, making sure that the sweatband is placed comfortably on the subjects' forehead. Also make sure that the accelerometer is placed on the back of the head.
4. Place the wristband on the subject making sure that it is placed carefully and comfortably on their wrist.
5. Place an auxiliary cable from in the auxiliary output port of the computer.



Figure B2 -Laptop Connections

6. Place the auxiliary cable with auxiliary jack connection into the input port of the PA system.



Figure B3 -Connecting Auxiliary Cable to PA System

7. Turn on the PA system.
8. Open the application execution file.

Using the device

1. When the executable file is opened the calibration sequence will begin. This can be seen in Figure B4.

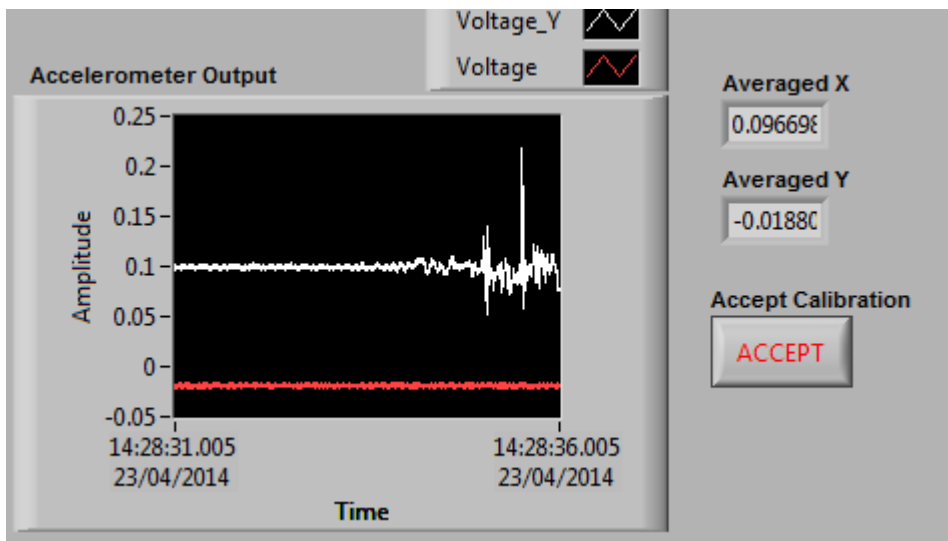


Figure B4-Calibration VI

2. Keep the wristband and headband in a neutral position and steady for about 5 seconds. The two voltages should remain relatively constant at this stage. This can be seen in figure B5.

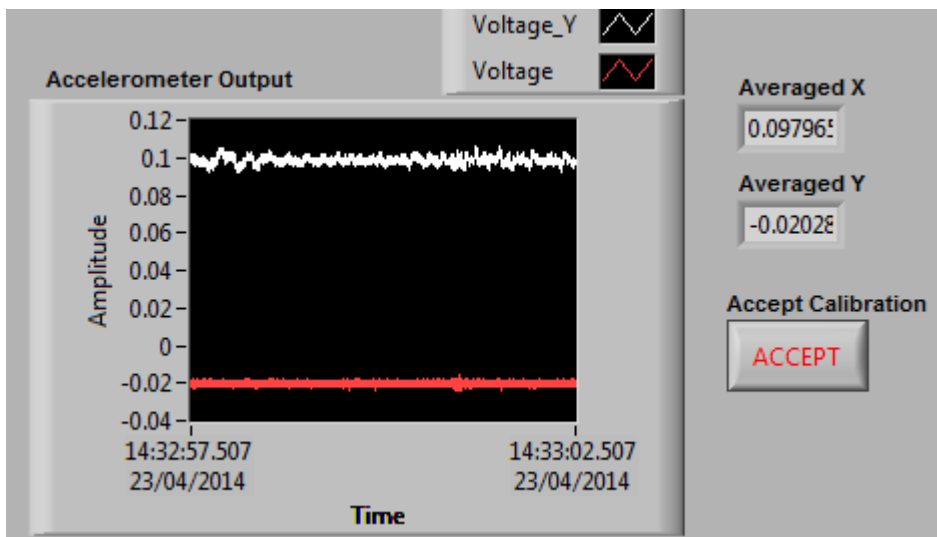


Figure B5-Accurate Calibration

3. When sufficient time has passed press accept (approx. 5 seconds). This will start the music making programme.
4. Press the relevant button to start the device, for example the guitar button. The display can be seen in figure B6.

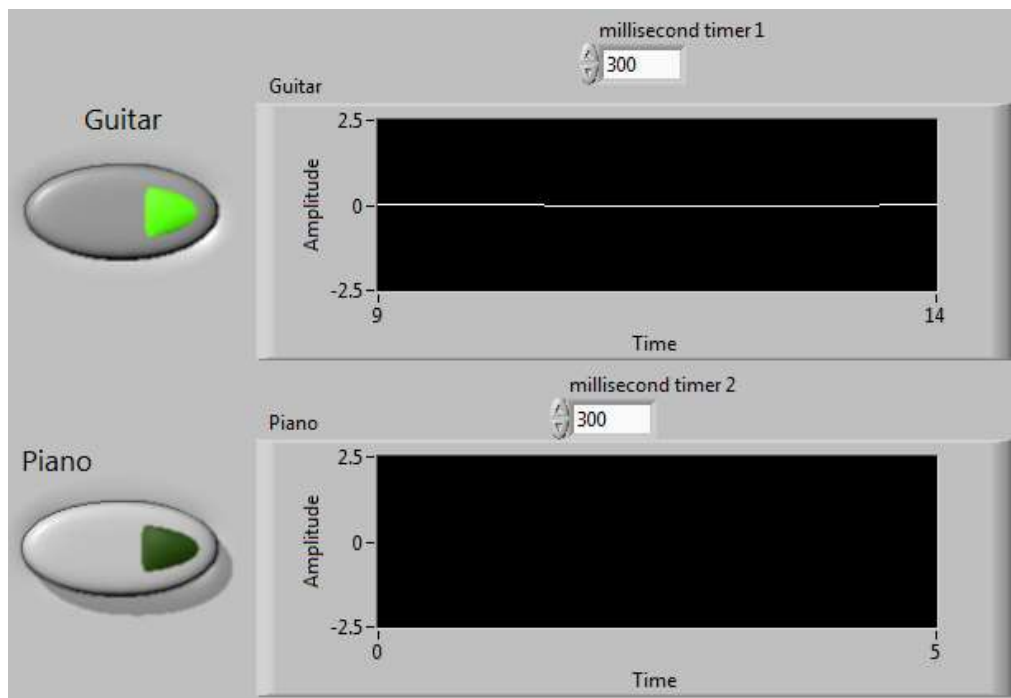


Figure B6-Application Display

5. Move the arm up and down and the head forward and back to create music, depending on the programme.
6. To stop the device press the stop button located at the top of the front-panel. This is illustrated in Figure B7. Similarly press the refresh button to start again.



Figure B7 -Starting and Stopping Device

Appendix C

Systematic Design of Music-ability™

Introduction

Goal

The goal of the project is to provide a product that allows a subject with cerebral palsy to create sophisticated music with basic movements.

Why is the product necessary?

Cerebral palsy is a very limiting condition and it affects many aspects of life, music is a great way for people with the condition to come together and enjoy themselves. There is niche market available for this product because people with certain disabilities cannot use the current adaptive music technology available. In the case of the magic flute many people have limited lung capacity and cannot operate the instrument. Another aspect which this project addresses is that current adaptive music technologies have many limitations and do not take full advantage of the movements available to the subject to create sophisticated music. This can be seen with the sound beam because notes cannot be skipped and seems to be a method to join in with other musicians but does not allow the subject to be expressive.

A systematic design has been carried out on the method of recognising the movements, analysing the movements and giving a musical output. Systematic design is a step by step process and each step allows the designer a clearer image of the possible solution. The process can be seen in figure C1.

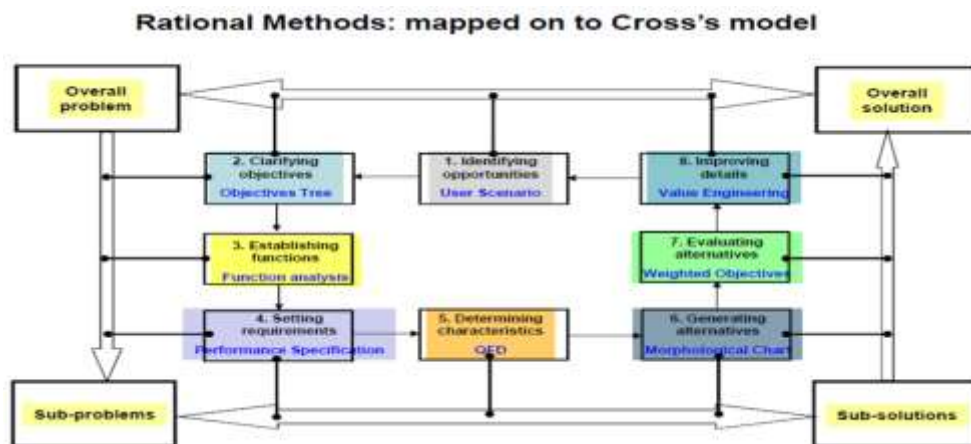


Figure C1- Cross model (21)

Clarifying objectives

Figure C1 shows an objectives tree which highlights the primary aspects of the project whilst elaborating on how these aspects will be fulfilled. Clarifying the objectives at the beginning of the design provides a clear understanding of what is wanted from the product upon its completion.

Integrated features:

- Records movements from subject in an accurate and dynamic manner
- Outputs music in a clear and concise manner
- Musical key and instrument sound easily changed
- Can skip notes and place emphasis/effects on certain notes eg distortion
- Can be integrated with other musicians but also can be used singularly

Safe:

- Must be used in a safe manner to eliminate risk of injury to the user and to people in surrounding environment
- Must have appropriate safety features eg safety stickers
- Contain fuse in case of power surge

Convenient:

- Doesn't occupy too much space and is easy to store
- Easy use for the operator with simplistic controls
- Not too expensive but quality assured
- Long design life and easy to set up

Environmental Impact

- The product should be manufactured from recycled materials where possible.
- It is important that the product can be recycled at the end of its design life.
- As the product will need a power source, it is imperative that it is efficient as possible
- Must have a small carbon footprint to reduce effects on the environment

Objectives Tree

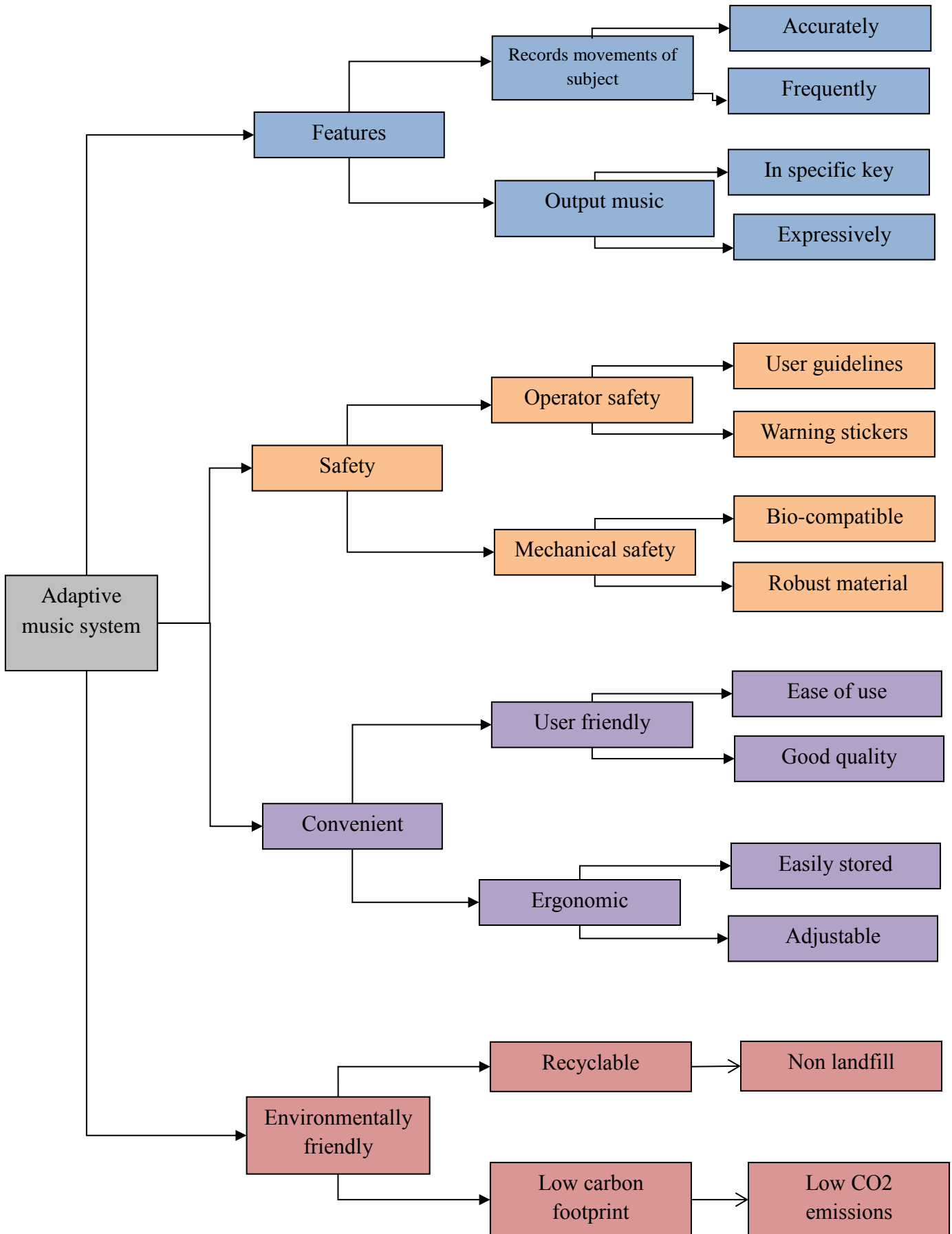
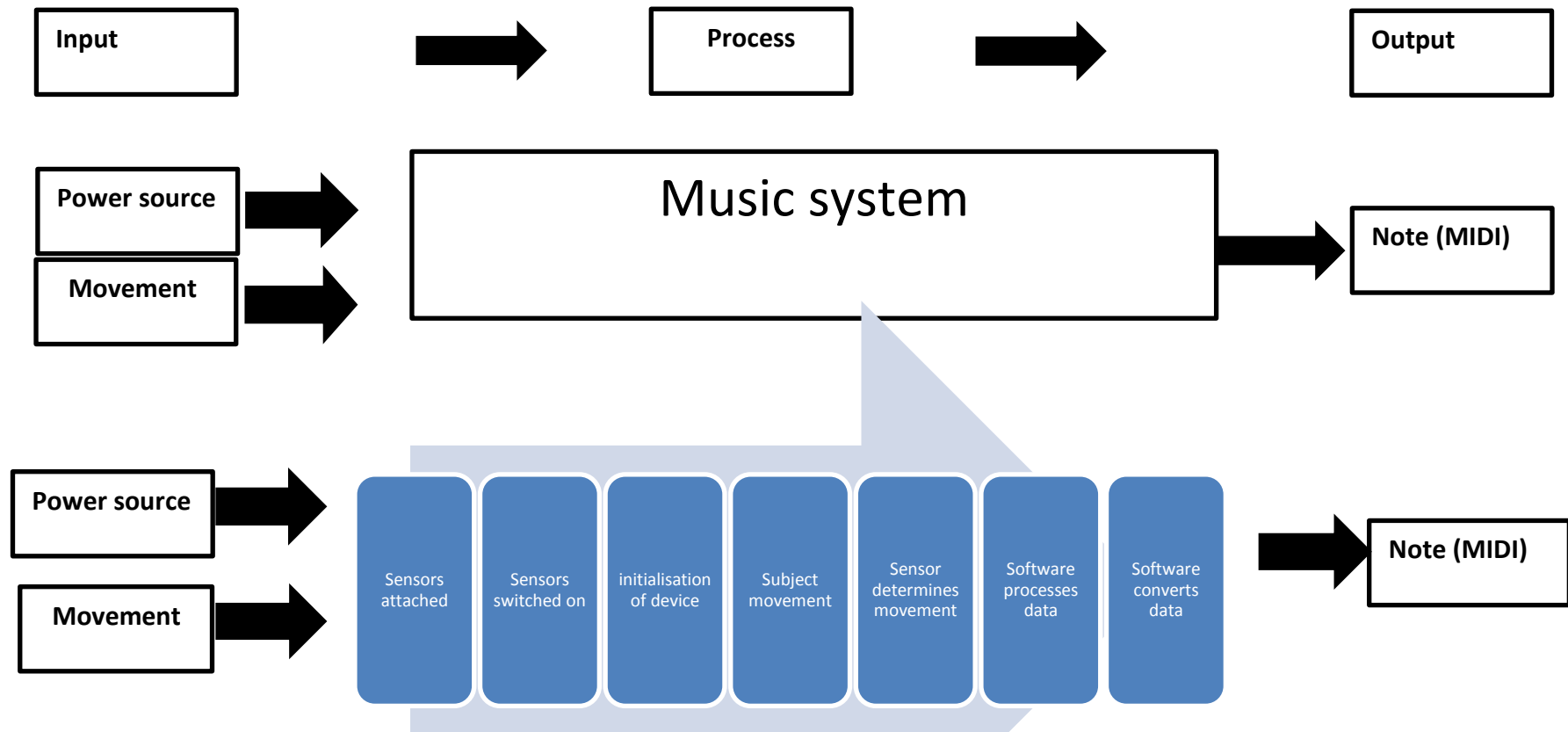


Figure C2 -Objectives Tree J.Fogarty 2014

Establishing functions

This section highlights the anticipated operation of the sensor and data processing system to give the desired output. The inputs, outputs and required process operations can be seen in figure C3. Establishing the functions allows the designer to see the step by step process and what is exactly is needed to give the required output.



Setting Requirements

Setting requirements is vital in understanding and determining what is crucial to the design and what aspects are less important. It breaks up the project into “demands” and “wishes”. By doing this it reduces un-necessary components of the design and allows the designer to prioritize certain aspects. Due to the complex design of the project there was always going to be time constraints and so it was important to know what parts of the design could be removed.

Table C1-Setting Requirements J.Fogarty 2014

#	Demand Wish	Performance Requirements
1	D	Output specific note
2	D	Operated in room temperature
3	D	Be quick response time
4	D	Integrated with other musicians
5	W	Have different sound effects
6	W	Have design life of 5 years
7	W	Display results in MIDI
8	D	Have a display system
9	W	Portable
Manufacture Requirements		
10	W	Relatively inexpensive to make
11	D	Low production time
12	D	Should comply with relevant manufacturing standards
13	W	Limited waste
14	W	Limited skill required for manufacture
15	W	Produced in an ecologically friendly manner
Operation Requirements		
16	D	Comfortable and safe to use
17	D	User Friendly
18	D	Easily calibrated
19	W	Doesn't use too much power
20	W	Aesthetically Pleasing
21	W	Easy to start up
22	D	Appropriate gestures are recognised
23	D	Music can be created expressively

Morphology Chart

All possible methods of doing all operations are listed in the morphological chart in table C2. This provides a clear illustration of all of the possible options for each feature and this aided greatly in evaluating each option. The method of how the product is used is explained by the morphological chart.

Table C2 - Morphological Chart Author 2014

<u>Feature</u>	<u>Means</u>			
Primary area for gesture recognition	Phalanges	Wrist	Upper arm	
Measurement of Gesture	Accelerometer	Gyroscope	Ultrasonic sensor	Video recognition
Secondary area for gesture recognition	Neck	On top of head	Face	
Software for analysing data	Labview	Arduino		
Method of acquiring data	DAQ module	Micro-processor		
Method of signal transmission	Blue tooth	Transmitter and receiver	Wired	Infrared
Type of musical command	Modulation	Note creation		
Programme for music production	Ableton	Reason	GarageBand	
Power source for sensors	Battery	Mains		
Method of output	MIDI	Audio		
Method of displaying results	LCD screen	Computer	System of LEDs	Smartphone

Quality function deployment

In a QFD, a relationship between the customer requirements and the functional requirements are examined. In this case the customer requirements and their weight were provided by the organisation SoundOut. It is extremely important for the project to be a success in terms of what the customer wants. The functional requirements are provided by the previous steps in the systematic design. The relationship between the functional requirements is also examined. This process makes the designer focus on what is needed and the interdependence of several factors of the project.

Correlations			Relationships		
Positive	+		Strong	●	
Negative	-		Moderate	○	
No Correlation			Weak	▽	

Row #	Customer Importance(1-10)	Customer Requirements (Explicit and Implicit)	Functional Requirements							
			1	2	3	4	5	6	7	8
			Range of accelerometer (±G)	Dynamic output (analog signal)	Sensitivity (±G)	Method of holding sensor	MIDI output(bits)	Overall mass of sensor(g)	Method of data acquisition	Method of data processing
1	3	Expressive Music	●	●	○		○		▽	▽
2	4	Volume Control		○			●		▽	○
3	4	Pitch Control	▽	○			○			●
4	6	Play along with others				▽	●		○	●
5	7	Easy Controls	○	●	○	○		○		
6	5	Music can be recorded					●		○	●
7	3	Different sound effects			▽		●		○	●
8	6	Feel of a musical instrument	○	○	▽	●		●		

Table C3 -Quality Function Deployment J.Fogarty 2014

Appendix D

Accelerometer Housing Design

The designed accelerometer housing allows the wires to reach the accelerometer whilst also protecting the accelerometer from damage. To aid in the explanation the design is broken into two parts. As can be seen from Figure D1 the accelerometer can be placed in the centre of the housing and can be glued in place with glue suitable for the accelerometer such as cyanoacrylate. The design would hold the accelerometer firmly in place. The hinges can be seen in yellow whilst a clip is to be placed around the extruded section on the opposite side.

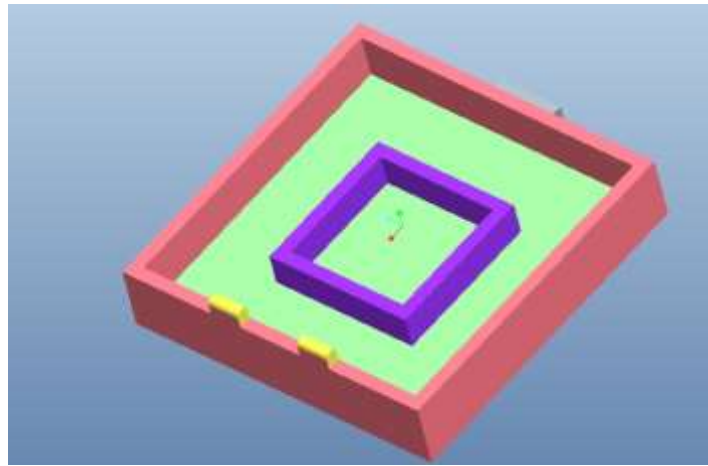


Figure D1 -Lower Section of Accelerometer Housing

The top half of the housing contains a 10mm diameter hole which can be seen in Figure D2, this allows the wires to reach the accelerometer. It also contains the clip to fit over the extruded section to self-close the accelerometer housing. It also has sections where the hinges can connect.

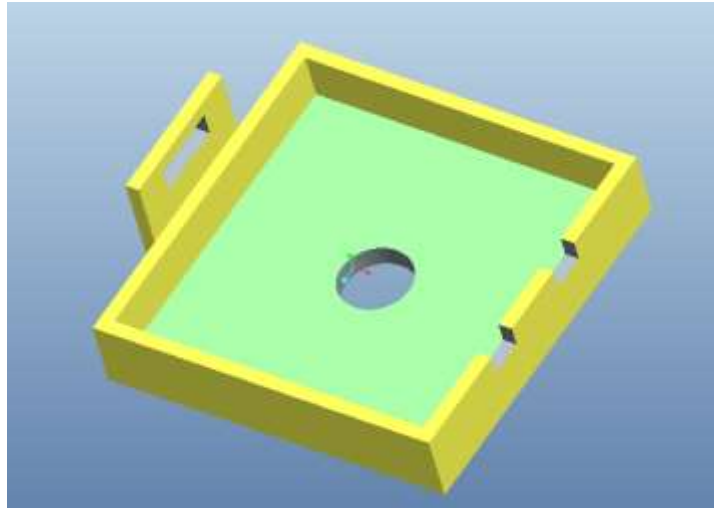


Figure D2- Upper Section of Accelerometer Housing

The Housing is designed so that it can be opened if the accelerometer needed to be removed or checked, if problems were occurring. An assembly of the two parts can be seen in Figure D3. The two sections have different colours to make the assembly easier to illustrate.

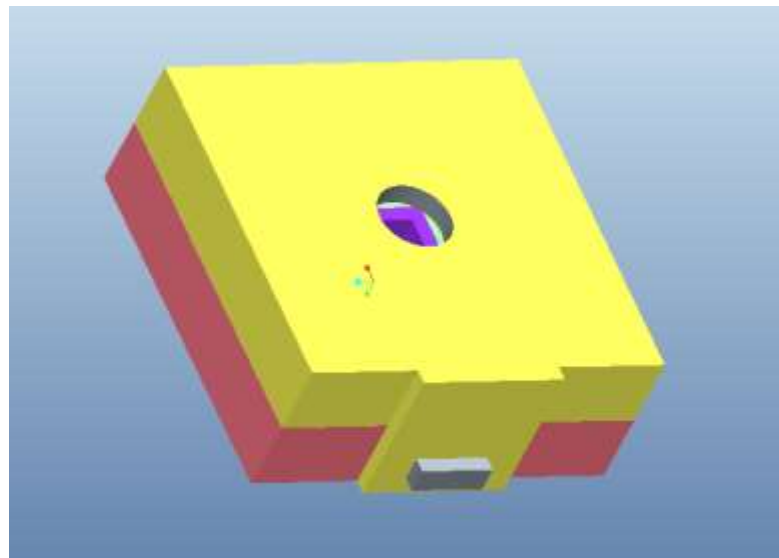
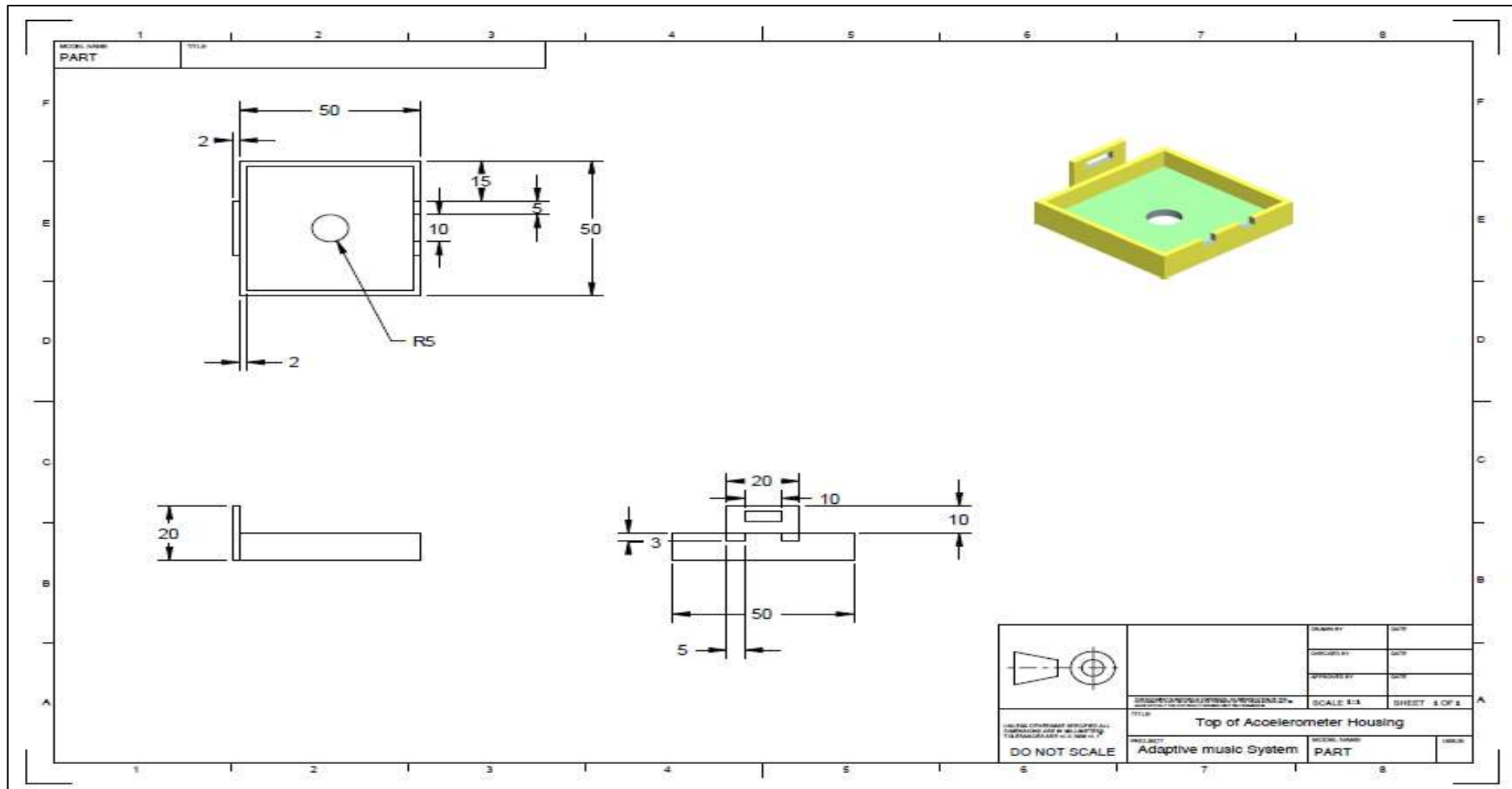


Figure D3-Assembled Accelerometer Housing

A suitable material to make the housing would be polycarbonate because it is a durable material. It has high impact-resistance and low scratch-resistance. Polycarbonate is also easily worked, moulded and thermoformed.

Dimensions for Accelerometer Housing



Design and Development of an Assistive Technology Music System for Sufferers of Cerebral Palsy

