A Motion Capture/ Detection Device for Skateboards using an Arduino 101

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BSc. Computer Science Dissertation

April 2017

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For my Mum, Dad, Sister and Dog

ABSTRACT

This dissertation provides some guidance on the use of LaTeX in the production of a dissertation. It is intended to serve as an illustration of some basic LaTeX commands and the use of the `thesis.cls` file. The structure of the dissertation, the organisation and naming of directories and files and the content of the chapters is illustrative only. You should modify all these aspects to suit your own requirements. It is assumed that you are working with a modern LaTeX installation that includes packages such as `natbib`, `url` and `graphicx`.

DECLARATION

I haven't copied anything, honest. And nobody else wrote this stuff. Just me. And if I've even so much as glanced at somebody else's work, I've referenced it properly.

You can fail me if I'm telling lies.

ACKNOWLEDGEMENTS

My supervisor is an exceptional chap without whom this dissertation would have been possible. The University should bestow upon him immediately the title of Professor and adjust his remuneration accordingly.

Other people, too, have been quite helpful in getting me to this stage in my career.

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1. INTRODUCTION

1.1 Background

The aim of this project was to create a motion detection device using the Genuino 101 board that could be attached to a skateboard to record when skate tricks are performed.

The initial motivation of this project was the interest I had in doing and embedded systems project as the general theme for my final year project at university. The topic of embedded systems is something I find particularly interesting. With the amount of smart home technologies cropping up these days and the ease in which to get user friendly hardware someone like myself can use, I wanted to create one of my own.

With this in mind I looked into how I could create something I could use alongside my hobbies. At the time when I was thinking about a Smart device I could make I had just started taking up skateboarding. From here I wondered if you could use a device to record the distance you have travelled on skateboard, however when it comes to being good at skating it is not down to the distance you have travelled but down to tricks you can perform. I then started to think about a way of being able to digitally record when a trick has been performed. Which then led me to conclusion that by using an accelerometer you should be able to distinguish each trick due different changes on all 3 axes (X, Y and Z).

Once I figured out it might be possible I to do this I did some research on the technology available and found it was possible to buy Micro processing boards with accelerometers in built, but as well as this, Bluetooth capability. This then led me onto the idea of creating an app for a smartphone which would pair with the device and provide an interactive way for myself or another user to have this data recorded by the device presented to user in a very friendly way.

After researching the different alternatives, I tipped the Genuino 101 Board to be the best Microprocessor as a solution to this idea. This was down to code libraries looking relatively familiar as it is derived from C and the fact there is already an available application from the company for smartphones to pair with the device and push simple commands to the board which endorses the type of technology I wanted to use for this project.

The device sends the data it records to a paired smartphone via Bluetooth. The smartphone receiving this data has an application installed to interpret the data

and determine which skate trick has been performed, as well as how many times it has been performed or attempted. I also developed the application as part of this project.

The motion is monitored and captured using an accelerometer and gyroscope. The application records each trick individually as each trick you can perform on a skateboard causes the board to move in a different way.

With the Genuino 101 attached to a skateboard, this unique movement provides unique x, y and z-axis values which the accelerometer is able to detect and send to the smartphone via Bluetooth as the Genuino 101 has accelerometer, gyroscope and Bluetooth components already on board. I used the Arduino SDK and coding library to create an on board operating system that will start taking readings of the raw data values produced by the accelerometer on the Genuino 101 when triggered by request from the user using the smartphone application. This on board operating system is also able to handle the pairing of a smartphone device via Bluetooth and establish a protocol to send the accelerometer data by.

The application prompts the user to start a Skate Session, once the user has done this the application will start processing any data that it receives from the board attached to the Skateboard. During this Skate Session, the application receives data from the onboard motion detector; recording what tricks have been performed, how many times they have been performed and how many times they were successfully landed. All this information is then presented in real-time and then summarised for the user at the end of the Skate Session in a user friendly manner.

This report will address the issues presented to me in order to complete the project in the form of a literature review. As a result of this review I will explain the issues faced to me over the projects life -cycle and evaluate the techniques I used to overcome them in order to complete it.

One of the main issues and also a key theme in this project, that will be discussed, is the creation of embedded systems and the issues faced when creating them such as Concurrency, Interrupt Handling and performance issues. Furthermore, to the typical embedded systems I will talk about the issues faced when sending data via wireless communication and investigate the problems presented by the practice of using accelerometers for motion detection.

With the issues stated above to be seen as one of half of the issues that have to be investigated for the project, I also had to investigate UI and UX as I wanted the application to be very user friendly so that it is simple for anyone to use. For this I had to do some research on the best practices to use when creating user inferences and how to create a good user experience. These practices will be discussed as part of the literature review.

The Report will also explain in detail all the methods and processes that I went through in order to complete this project. Included in the Synthesis section is a through discussion of all practical work done for the project, this will cover aspects such as the Design work done for the applications user interface, the

coding done for the application and also the coding done to create the embedded system that will be loaded onto the Genuino 101.

The report will then go on to evaluate this work. This evaluation will include a critique of the products fitness for purpose against the specification and requirements I laid out before undertaking the practical work.

As part of this evaluation I will also asses the methods I decided to use in order to complete this project and decided whether the methods I used where the best possible solutions to the problems I faced. I will talk about the skills I already had which came as a great benefit to project as well as discuss what skills I have developed or learnt entirely from carrying out this project.

2. ANALYSIS

2.1 Introduction

The creation of an embedded system presents many issues as it interacts with a physical environment which can throw many different exceptions. Embedded systems must be able to handle these exceptions to maintain its integrity.

Henzinger and Sifakis claim theyre two key areas of constraints on embedded systems in physical environments, reaction constraints and execution constraints. Reaction constraints include deadlines, bandwidth capable on the data buses and jitter. The execution constraints refer to processing speeds and power that the system must be able to handle/ keep up with. [1]

When thinking about the different constraints I would have to work within for my project these two areas certainly formed a basis on which I built my requirements and choose my relevant hardware.

In terms of the reaction constraints, deadlines will be highly important and will certainly affect how I schedule my tasks and manage shared resources. I will be giving the task which posts the recorded data to the mobile application very strict and precise deadlines so that the task responsible for monitoring the boards movements is given as much time on the CPU as possible when the system is running. Jitter could be overcome through implementing a time triggered system but this kind of system also presents problems such as high latency which I can avoid by using an event triggered architecture. This is something that I must consider and is discussed in more depth in this literature review.

In terms of execution constraints, I do not have any problems, the microcontroller I have chosen to use is an Arduino 101 this board has a clock speed of 32 MHz [2] which will be more than enough processing power to perform the tasks that are needed by my system to collect data from sensors and send this data to a mobile application via Bluetooth.

The power that system needs to be able to handle wont be a problem either as the power supply for the board will need to small enough so that it fits on the skateboard without effecting the ability to use a great deal. This influenced the decision to choose a 9V power supply for my board which is perfect as the recommend voltage supply for this board is between 7 12 V with the board operating at 3.3V [2].

2.2 Embedded Systems Issues

2.2.1 System Reliability

Reliability and Efficiency is going to be a key aspect in this project and I must consider the systems reliability it two mains areas, collecting the data from the sensors correctly and then sending it to the phone reliably. In a way, I am subject to a catch 22 type of situation where increased reliability may mean the efficiency of the system decreases and vice versa. For example, if I look at how I am going to develop the embedded system for this project I could weigh up critical systems engineering against best-effort engineering. These are two very different approaches; critical systems engineering is best suited for hard real time systems where as best effort is favoured for soft embedded systems.

The hard-real time approach leads to low utilisation of system resources. On the other hand, soft approaches take the risk of temporary unavailability [1] Applying this to the system I want to create I would opt for a best effort soft real time system approach as I will be utilising several system resources such as the accelerometer, gyroscope, Bluetooth chip and possibly pressure sensors. I will be using some if not all (at times) of these resources is tandem so going for a hard time approach such as critical systems engineering may be costly to how efficiently the system will run.

By choosing a soft real time approach I will have more dynamic resource allocation which will be important when using several different components on my microcontroller at the same time. This will also allow me to consider other performance metrics such system performance to be taken equally as seriously. [3]

The down side to this however is I may experience degradation of the systems integrity; I could run into issues where tasks of some data capturing components experience starvation and are blocked of their ability to be able to post their data onto the data bus. This issue could be avoided using hard real time approach as I could schedule the system to give each component and task a set block of time using the processor to post the data. This however I can still overcome this in soft real-time system by implementing buffers to store the data into until the bus becomes available.

2.2.2 Concurrency

Concurrency is another problem within the embedded systems design challenge that I had to consider as parallelisation of processing tasks in digital signal processing tasks and algorithms is highly important and increases the systems capability. [4]

I need a highly concurrent system as I will have at least 2 components capturing and posting data at the same time. Thus, I am planning on using a higher sample rate for the components such as the accelerometer and gyroscope than

I initially planned. By doing this, if one components task is not able to run as the CPU is busy then less samples will be missed and the general pattern that performing the skate trick creates will be less distorted.

I was initially going to set the sample rate at 80 samples per second (1 sample every 12.5 milliseconds) however if I scale this up and choose a sample rate of 160 samples per second I end up with 1 sample every 6.25 milliseconds. By doing this if a process if denied access to the CPU for 10 milliseconds it will miss 1 sample the same as using a sample rate of 80 however I will have twice the number of samples before and after to use to predict what the pattern would have looked like if the sample wasnt missed.

Getting my systems concurrency correct is highly important to the project as a lot of tasks, critical to the overall system performance, will be running at the same time. For example, I will have tasks running that monitor the accelerometer and gyroscope at the same time alongside tasks responsible for processing the data and sending it off to the mobile application to be pushed up to internet. The way that I will do this is by following a model coined by Norbert Schramm which can be seen in the figure below [4]:

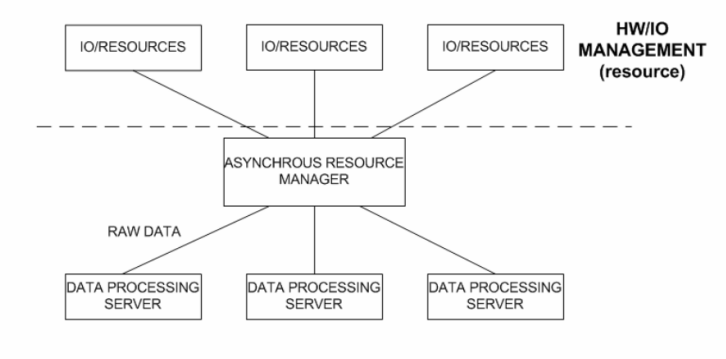

Fig. 2.1: Asynchronous Resource Manager

As you can see theyre several I/O resources that feed into an asynchronous resource manager which provides access for the data processing elements. In terms of my project the IO/Resources boxes on the diagram represent my accelerometer, gyroscope and pressure sensors as these are the components providing the raw data.

The asynchronous resource manager block you see in the middle will be the Bluetooth data protocol that allows the mobile application access to the data, it was also oversee what order messages are getting sent in. The mobile phone in the case of the diagram is the data processing server. The reason that mobile phone takes the role of the data processing server is that according Schramms explanation of the model the role of the data processing server is to convert raw data (which is what will be given by the accelerometer during run time into a specific data type which provides input for an action to be executed.

This now gives me all the components needed for an execution module. Using the method presented by Schramm the execution module is just simply a lightweight thread, here is an example of a thread [4]:

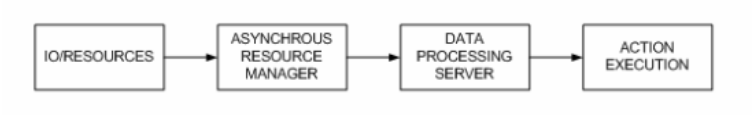

Fig. 2.2: Execution cycle for a general thread

Having a light weight thread means that I reduce my resource requirements and gain faster context switching which is something that I require for my system to operate the best it can. Fast context switching is desired in my system as I want post data as quickly as possible so that the tasks responsible for capturing the data have as much time on the CPU as possible so that the data readings are as accurate as they can be.

2.2.3 Time Triggered vs Event Triggered

Running a concurrent system will lead me onto my next consideration which is the style of interrupts I should use in the system for the microcontroller. For this I have two options; time triggered interrupts or event triggered interrupts. Time- triggered (TT) systems are best suited for regular operation of distributed control systems but with them include the issue of high latency across the systems various buses, however time triggered architectures remove any possible jitter between tasks. [5] This is something that would be highly desirable to my system as I want system to be very efficient during context switching so that when the task to post recorded data to the phone runs the CPU is given back to tasks responsible for recording the data as quick as possible.

On the other hand, with time triggered events carrying the burden of high latency I feel that this will cancel out the fact this architecture removes jitter from the equation. If there is a high latency on the data bus the tasks which post the data to the mobile phone may have to spend time on the CPU waiting for the data to arrive from the tasks monitoring the various sensors around the board.

In addition to this the very way I want my system to work is event triggered, if there is a sudden change in the values of any of the sensors then this must mean a trick has been performed at this point I will want to make sure that the tasks responsible for posting the data and sending it to the phone can run. In an event triggered system data is sent immediately using an interrupt mechanism whereas with time triggered systems there can be a delay based on the polling period of the TT system. [6] This reinforces my decision to develop an event triggered system, I will be able to send data off the mobile as soon as a trick is performed using a ISR and I will also reduce the latency within my software.

2.3 The Genuino 101

2.4 Neural Networks

It relies on Fig. **??** to illustrate an essential concept. Another (better ?) approach to including graphics in a LaTeX document is to put a TikZ/PGF (Fauske, 2011) program directly in the document.

2.5 More advanced stuff

And here is some more such stuff which is on a sufficiently different topic to deserve a section of its own. This chapter may well contain the majority, although not all, of the references (Abrial, 1996; Alur et al., 1992; Ben-Abdallah and Lee, 1997). Consult a reference such as (Wikibooks, 2010) for information on how to include citations when using the Harvard referencing system.

3. SOME DESIGN AND IMPLEMENTATION STUFF

3.1 Introduction

There will probably be more than one chapter of synthesis. None of which will be called 'Synthesis'. This is the chapter where the reader is introduced to the design and/or implementation in a software development project. Your project may not fit this description and so you may not have a chapter like this.

3.2 Design

Now we get down to the nitty-gritty...

Heading 1	**Heading 2**	**Heading 3**
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Do it all again	Do it all again Do it all again Do it all again Do it all again Do it all again Do it all again	Do it all again

Tab. 3.1: Using the `tabular` environment

Clearly, Tab. A.1 provides a thoughtful summary of a large amount of information.

4. EVALUATION

4.1 Evaluation of the work done

4.2 Evaluation of the project process

5. CONCLUSIONS

This dissertation has described the use of LaTeX in the production of a dissertation. The work has been tested on more than one student (see Chapter 4). It is jolly useful.

APPENDIX

A. TERMS OF REFERENCE

Terms of reference should be first appendix.

A.1 Project Title

A Motion Capture/ Detection Device for Skateboards using an Arduino 101

A.2 Project Background

A.2.1 Why this project?

The aim of this project is to create a motion detection device using a microcontroller that can be attached to a skateboard to record when skate tricks are performed.

The initial motivation of this project was the interest I had in doing and embedded systems project as the general theme for my final year project at university. The topic of embedded systems is something I find particularly interesting. With the amount of smart home technologies cropping up these days (Gartner is predicting a typical family home could contain more than 500 smart devices by 2022, but right now, most consumers see smart home as a nebulous term without a clear value proposition. - Gartner 2015) and the ease in which to get user friendly hardware someone like myself can use, I wanted to create one of my own.

With this in mind I looked into how I could create something I could use alongside my hobbies. At the time when I was thinking about a Smart device I could make I had just started taking up skateboarding.

From here I wondered if you could use a device to record the distance you have travelled on skateboard, however when it comes to being good at skating it is not down to the distance you have travelled but down to tricks you can perform.

I then started to think about a way of being able to digitally record when a trick has been performed. Which then led me to conclusion that by using a microcontroller as a motion detector you should be able to distinguish each trick due different changes on all 3 axes (X, Y and Z).

With the world of Skateboarding not really incorporating technology so far in its lifespan I thought that this would be a good opportunity so see if I could

pioneer something myself that would be a use to the community as a whole if they wanted to use it.

Primarily this project is aimed at developing something for intermediate to advanced skateboarders so that they can record and look at the tricks they have performed over the course of a day skating for example the data could also be used in such a way to record how many tricks a skater has performed over the course of a month or a year. This is something that hasnt yet been created, I wondered why this hadnt been tried yet but couldnt think of a reason why as the logic behind detecting a trick using a motion detector seems sound.

However, this technology could be useful for Skateboarders regardless of their ability and could actually be of more use to beginners if I developed this project on further to use the data of the motion detector to suggest what the skateboarder needs to do in order to land the trick they are trying to perform.

Following on from this I could expand on the product that completes the initial objectives for this project and use the technology I develop to improve it so that it can use the data to monitor the form of the trick (how well it is executed). This would be something that could be very useful for skateboarding competitions as it will help judges to recognise how well a trick was performed. With skateboarding being accepted into the Olympics as a sport for Tokyo 2020 this kind of technology would be potentially sought after.

A.2.2 What issues will I face?

There are several issues that are presented to me be taking on this project. Firstly, I will need to find a place on the skateboard where the microcontroller can go without disrupting the users skating.

The point of doing this project without taking this into consideration would be flawed, having the microcontroller in a bad position could limit skateboarders ability to do certain tricks. I couldnt place the microcontroller on the top of the board as it would make feet positioning difficult which is a major part of performing skateboarding tricks.

This means that the microcontroller has to go on the bottom of the board, as a result I will have to face the issue of choosing a place on the bottom of the board to put the microcontroller which will firstly protect it from damage on impact of landing tricks but also placed in such a position that all grind tricks can be performed without a problem for the skater.

Another issue as well as a main objective within this project is determining the approach for detecting when tricks are performed. I know that each trick you can perform causes the board to move in a different way and knowing this means in theory it will provide different values when being monitored by a motion detector.

The problem is that different gradients and different surfaces will cause the motion detector to be at potentially different starting positions each time a

trick is performed. I will have to find a way of creating the program in such a way where this does not matter and the trick can be picked up regardless of its starting position.

The requirements needed of the embedded system that I will create generates issues that I will have to overcome in order to complete this project. A common issue with embedded systems is concurrency. This is something that I will definitely have to look at as I have hardware components on the board running concurrently.

The microcontroller will have to read the data from the motion detection components as well as maintaining a connection to the mobile device and posting the data to it. This will happen concurrently so I will have to look at solutions to prevent problems such as deadlock and starvation occurring. (Due to the constrains of embedded hardware and use cases of embedded systems, specific concurrency solutions are required. Schramm and Sabo 2008) This means I will have to evaluate several different approaches specifically to creating concurrent systems and choose which one I will implement based on the specification I set out for the embedded system.

Other common embedded systems I will have to overcome include: making my system reliable, predictable and suited for a real time environment. These issues will be discussed thoroughly in the Literature review I have to write as part of my project analysis section.

A.3 Proposed Work

A.3.1 Sourcing the perfect microcontroller

Before I can begin the development section of this project I need to source an appropriate microcontroller based on two major factors:

1. Having all the components I need for the motion detection and communication to a mobile phone. (Accelerometer and/or Gyroscope as well as a Bluetooth Module)
2. Being as small as possible so that it is not taking up too much room on the bottom of the skateboard.

I will then decide where the microcontroller will be placed on the bottom of the skateboard which subsequently will give me my size specification needed for the microcontroller, leaving me with the task of finding a board of the specified size with all the relevant components I need.

A.3.2 Create the Initial Embedded System and Capture Test Data

The main challenge of this project is to establish how I will distinguish each skate trick as and when it is performed. This will be done by creating an embedded system to analyse data generated by either an accelerometer, gyroscope or both working together in tandem. I will collect the test data using an open source program called Processing (Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts. Processing Website 2016) This software will draw a graph in real time based on the position of my microcontroller using data produced by the relevant components.

For this initial test I will be using a serial connection between the PC and microcontroller as this will be the simplest way to get my microcontroller hooked up to the Processing application to start recording data. I will place the microcontroller connected to the PC on a skateboard. Once the device is attached to the skateboard I will replicated the movements of the skateboard performing certain tricks. By doing this I will be able to observe, via the graph drawn by Processing in real time, how the movement caused by each trick affects the data values given by the motion detection components.

By analysing this data, I will be able to come up with an approach for processing the data when it is posted online so that it can be converted from raw data into a representation of this data in a form of what tricks have been performed and how many times they were performed later on in the project.

By carrying out this section of the project I will be able to evaluate how difficult the project will be too complete.

A.3.3 Give the Microcontroller Bluetooth Capability

Once I am satisfied with the data I have collected, and analysed it enough to come up with a solution to the problem of distinguishing and recording a skate trick, I will take on the task of getting the microcontroller connected to a smartphone device via Bluetooth. This will entail adding to the initial embedded system so that it can use the on-board Bluetooth module to make itself available for connection to a mobile device.

How this will be done will depend on the Microcontroller that I purchase, some microcontrollers already have applications for Android and iOS devices that can be used to control components such as the on-board LEDs. Although I will not be using the LEDs specificity in this project it will give me a good framework for establishing the Bluetooth connection as I can look at the source code for these applications and see how the connection is made.

As a result of this section of work I will have a basis for the mobile application needed for my gateway from the microcontroller to the internet. However, for this section the application will be very basic and its only real function at this

point will be to establish a connection from the microcontroller to the mobile device so that I can start working on sending the data from the board back to phone to then be pushed onto the internet.

During this phase of the development I will study the Bluetooth stack protocol so I have a solid understanding of its workings so I can identify any issues that may occur using Bluetooth for the wireless technology involved in this project.

A.3.4 Create the Mobile Application Gateway

During this phase of the development I will develop the protocol by which the data will be sent from the microcontroller to the mobile device. Initially I will store the data received by the application into the mobile phones memory so I can view it. From here I will be able to see whether the data is being transmitted to the phone correctly and consistently. It will also show me if there are any differences in the data captured by the board when it is used properly to perform skate tricks rather than just emulating them myself.

Once I am happy with the way the data is being sent from the board to the phone when properly performing the tricks, I will then create an online database for this data to transferred into. This will require me setting up the database in way dedicated to receiving raw accelerometer or gyroscope readings.

When this database is then set up I will create a method within the mobile application that will post up the data receives from the board up to the internet and store it in the database I create on the web. If an internet connection is not available at the time of data capture, then the data will be saved into the phones memory so that it can then be posted online when a connection becomes available.

A.3.5 Presenting the Captured Data

The final phase of development work to be carried out for this project will be creating a form of web based application that will use the data that is stored in the online database. The web application will be used by the user to view the data that is stored and present in a friendlier way than just raw accelerometer or gyroscope data readings.

To do this I will use the methods created as a result of the data analysis carried out in the second section to distinguish between each trick and create a method or algorithm to translate the recorded data into presentable values such as Kick Flip or Pop Shuvit. To do this I am planning on creating a system in something like PHP or Python, this system will contain a method which will have a way of processing the case of each individual trick for example it could look something like this: I will use this sort of method so the application will be able to handle different tricks performed on the skateboard. Once I am satisfied that the method can interpret the data properly it is time to design the user interface, this will require me to brush up on some basic UI and UX

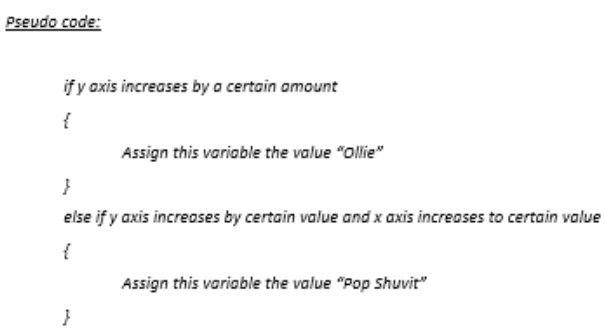

Fig. A.1: Pseduo Code

skills learnt in my previous 2 years of university. I would like the development of this project to be of use to other people as well so making this web based application well designed is important.

A.4 Project Aims

1. To investigate whether a motion detector can be used to record and define Skateboarding tricks as and when they are performed.
2. To create a mobile phone application which can receive data from a paired microcomputer that is attached to a Skateboard via Bluetooth. This application will display the data it receives in a user friendly manner.

A.5 Project Objectives

1. To write a literature review on the issues presented to me by creating an embedded system and what solutions I can use to overcome these problems.
2. To establish a method for how I can distinguish between different skateboarding tricks using the accelerometer and gyroscope.
3. Gather a thorough set of requirements to specify what the application and microcontroller are able to do when working in tandem.
4. To create an embedded system which can use a microcontroller to produce readings of raw data.
5. To establish a wireless protocol by which I can communicate this raw data produced by the microcontroller to a mobile phone.
6. Design user interfaces for all of the mobile applications use case scenarios based on the requirements I capture.

7. To create an application for mobile phones which uses the data received wirelessly from the microcontroller and presents this to users in an interactive way based on the requirements I capture.
8. Evaluate the microcontrollers ability to be used as a device to detect when skateboarding tricks have been performed.
9. Evaluate the performance of the application created to pair with the microcontroller and use the data it receives from it to present it user interactively.
10. Evaluate my performance during the course of developing this product and project as a whole including coding, time management skills and ability to work according to a schedule.

A.5.1 Learning Objectives

1. Investigate and understand what makes for good UI and UX then apply this to my mobile application development process.
2. To learn and understand how to transmit information wirelessly via Bluetooth and how to establish secure and reliable protocols for doing this.

A.6 Skills Required

A.7 Bibliography

Add References here

A.8 Resources

A.8.1 Hardware

- A Microcontroller to be used as a motion detector
- A laptop to install IDE on for programming the application and embedded system
- Smartphone to install and test the application on
- A skateboard to attach the microcontroller to

A.8.2 Software

- IDE for mobile application development
- A software called Processing which will present accelerometer readings from the microcontoller for me
- The Arduino development environment for writing the embedded system
- LaTeX for producing all documents
- MS Project for creating my project plan
- Adobe Illustrator for designing the application screens

A.9 Report Structure and Contents

A.9.1 Title Page

A.9.2 Contents Page

A.9.3 Abstract

The abstract will outline the project as whole. It will briefly mention the aims of this project and what work I have carried out in order to meet these aims. I will mention the methodology approach to the project and briefly mention the end result of the project.

A.9.4 Introduction

This section will discuss the reasoning for carrying out the project and outline the approach I will take for the development and what deliverables I will satisfy. The introduction will also outline what the other sections of the report will include.

A.9.5 Analysis

This section will be made up of 2 chapters. The first will be a literature review which will discuss the key issues I will face during the development of this project and evaluate the solutions to these problems in a critical way.

Literature Review

Within my literature review I will discuss 2 topics relevant to the work I am carrying out for this project. (Covers Objective 1).

Embedded System Design Challenge

In this section of the literature review I will discuss the main challenges and choices that need to be made when creating embedded systems. I will evaluate the different approaches for concurrency, scheduling etc. and explain the choices of methods I am going to use.

The Hardware

This section will justify my hardware decisions.

Machine Learning Techniques

I also discuss pattern recognition with digital signal processing evaluating the techniques I have available to me and which one will be best suited to the work needed for my project. (Detecting the skateboard tricks).

Requirements Commentary

The second chapter of this section will be discussion of the project requirements justifying where necessary and explaining how I captured the requirements. (Covers Objective 3).

Methodology Approach

I will discuss my methodology approach for this project comparing different approaches you can take and explaining why the approach I decided to take was the correct one for the development of this project.

A.9.6 Synthesis

Deliverables Commentary

In this section I will be discussing why the deliverables of the project are required for its completion.

Skate Trick Detection Analysis

An explanation of the process I went through to coin a method to detect when and which skateboardin trick have been performed. (Covers objectives 2).

Skill	Level of experience with this skill	Do I need to Improve this skill	How will I improve this skill
Researching for relevant literature	Moderate	Yes	Read up on research methods as well as working on the search criteria that I use to find references.
Requirements Gathering	High	No	Not applicable.
Data Analysis	Moderate	Yes	I have to look at trends previously when studying subjects such as statistics. I will improve this technique solely by gathering data for my project and looking at it and trying to determine what is means.
Creation of embedded systems	High	Yes	I am comfortable with the workings of embedded systems although I do believe I need to improve on this further for this project.
Mobile Application Development	Moderate	Yes	I will improve this skill through dedicating time to studying the development of mobile applications and apply this to my project.
Project and Time Management	High	Yes	Even though I am already competent in this skill, I believe I willimprove even further as I have never had to manage a project of this scale.
Working with wireless communication	Low	Yes	I have never worked with wireless communication before in any sense so this will be a whole new experience for me. I will learn this through studying methods of transferring data online and reading literature. I will also be able to reference the microcontrollers function librarys for wireless components.
Evaluation	High	No	Not applicable

Tab. A.1: Using the `tabular` environment

B. SOME DESIGN AND IMPLEMENTATION DOCS

This is the appendix that contains any software documentation, UML, ERD's, complete test plans and results ...

Include full documentation in the appendix and reuse fragments in the main body of the dissertation if they are particularly important or interesting.

C. CODE

And now a well-commented code-listing, do it 4-up so that it doesn't take too much room.

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