The Design, Development, Evaluation and Testing of a Boxing Performance Tracker

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Abstract - *The aim of this project is to develop a system that allows amateur boxers to gather, upload, view and analyse boxing training. This project allows users to evaluate where they most require improvement by looking at the statistics and graphs, for example: throwing very few punches after a 30 second burst of punches, suggests that their stamina or endurance may require improvement.*

The aims and objectives of the projects is shaped through researching advantages and disadvantages of currently available products, and user testing on members of the University of Dundee Boxing Club, to gather user wants. Testing is conducted before, during and after development, to find features and requirements desired and fully assess the system by following a user-centered design. The results show knowing the number of punches, speed and accuracy of punches is desired. From user testing, enhancements, features and future development is suggested which all help mould the final deliverable system.

1 Introduction

Boxing is the sport of hitting your opponent without getting hit back. Winning a boxing match in the judge's eyes can simply come down to landing more punches than received. Boxing is also a very popular training and weight loss method for people trying to follow a healthier lifestyle, and get fitter. With the ability to see statistics and visualisation of workouts, there is confirmation rather than assumption of getting fitter, healthier or stronger.

The emergence of new sensors/technology means it is now easier for sports and activities to be analysed, monitored and displayed in an easy-to-use format, which spectators and judges can read. Many sports such as football and basketball make use of sensors and technology in their sport to help referees, players and spectators gain statistics and insights.

The sport of boxing is no different. Sensors in sports are currently being used in events, such as HBO televised boxing events, through the use of a system called "CompuBox" [1]. The purpose of CompuBox is to count each punch thrown and landed, giving percentages for each of the fighters and give a perception of which fighter gave the best performance, in order to settle any potential controversies. There are 5 user groups in the sport of boxing. Each user group has different roles in the sport of boxing, with each benefiting differently from knowing how many punches, what type of punch and the speed/force of the punches landed were;

1. Referees, they ensure the safety and abiding of rules. They would benefit in knowing how damage a fighter is receiving, in order to stop the event if they feel a fighter may get life threateningly injured.
2. Judges, they provide a final verdict should the contest reach the number of available rounds. Knowing the number of punches and types of punches landed would assist in making a fair decision.
3. Athletes compete in the boxing match. Coming up to a match, knowing the number of punches and how fast they are throwing in training sessions would assist in preparing appropriately for their fight and can also compare training session statistics to the training sessions.
4. Coaches ensure their boxer is prepared before their bout and gives comments/advice in between rounds of the bout. They would benefit in knowing how their fighters are boxing in between rounds, so they can give advice. It would also allow the coaches to compare flights to training sessions
5. Spectators pay and are provided with entertainment from the match. They would want to see the number of punches throughout the fight to help see which fighter is winning.

Many practising boxers and coaches at amateur boxing clubs are currently unable to view progress and training statistics, but would benefit from such technology to track improvement, which is reinforced by Marco Chiappetta, claiming that "punch tracking technology and sensors aren't only useful for fitness buffs. Professional boxers and trainers can leverage the technology to quantify performance as well." [2].

1.1 Aims and Objectives

The aim of this project is to create a platform that allows everyday users as well as competitive amateur boxers gain statistics of their boxing training workout. This is aimed to be achieved by providing users with an interface that shows how many punches are being thrown, when they're thrown, how long for and how fast. The platform is intended to be user-friendly, by following a user-centred design.

Through these insights, the aim is for users to be able to use the statistics to track where they require improvement, for example, if it can be seen that fewer punches are thrown towards the end of a session, a can conclusion can be made that endurance/stamina requires improvement.

A further aim for the platform is to include portability, enabling access on any device, without the need to be plugged in. Alongside this, the platform aims to be easily accessible to people on all budgets, and with no requirement of software, wires or cables.

The final aim is to have no data stored, to allow users to have constant access without worrying about confidential data being leaked or exploited. There should be no need to login or log out, without exposing security issues. As files are uploaded, the system should not use storage space for uploaded files or information.

To bring the aims to fruition, the objectives are to:

1. Survey comparable products on the market
    a. Study the Advantages and Disadvantages of each
2. Study relevant pieces of literature to find issues and solutions in the academic world
3. Gather tests to explore what users want
    a. Find main features
    b. Find requirements for the system to be in budget for target user group
    c. Analyse products to access the most accessible for amateur boxers.
4. Develop a system that allows for upload and visualisation of raw data recorded;
    a. With the upload of files, graphs can be generated to offer visualisation of the session data recorded while training.
    b. A Punch counter can be created to show the number of punches thrown.
    c. Users should be able to compare sessions, allowing for self-improvement by comparing early and recent sessions, as well as competition with others, for example to see who threw the most punches in their training session.
5. Develop a system that allows for both portability and security;
    a. The platform should be available to be accessed on any device, without the need of cables to be plugged in.
    b. Alongside portability, the platform should be easily accessible to people on all budgets and without requirement of software, wires or cables.
    c. The system should have no data stored, to allow users to have constant access without worrying about confidential data being leaked or exploited. There should be no need to login or log out, without exposing security issues. As files are uploaded, the system should not use storage space on the device for uploaded files or information.
6. Perform user testing to evaluate the system in terms of usability, implemented features and visualisations.

1.2 Methodology

Steps were taken to ensure the aims and objectives set above were successful, these consisted of:

1. Regular meetings with supervisor, Dr Alison Pease, to ensure the project was running smoothly and in the right direction.

2. Study relevant pieces of literature that analyse and discuss the topic of sensors, from those used in sport and more specifically sensors being used in boxing.

3. Research was conducted on similar products available on the market to view their advantages and disadvantages to learn from them and implement a well-rounded system.

4. Research and testing of potential devices to use for development of the boxing performance tracker was conducted to evaluate the most suitable device.

5. User studies with members of Dundee University Boxing Club helped find what is sought after from a boxing performance tracker and what can be dismissed.

6. Constant design, development, enhancement and testing of the platform by the developer of the system.

7. Meetings with participants for testing purposes, beginning before development to gather requirements and features users wish the system to include, the last being after development to evaluate the successfulness of the requirements, features and visualisation of the system.

8. Self-Assessment of the system from the creator to identify what went well, and where enhancements could be made, picking out elements that could have been approached in a more advantageous manner.

1.3 Ethics

The project has successfully been approved by the Ethics committee in the form of a full submission of a Low-Risk Ethics form which was sent to the Ethics Committee prior to development and testing. As risk of physical discomfort or pain was low the submission of the form to the ethics committee was a Low-Risk submission. The participants and types of exercise that may be carried out have specifically been chosen so that they mitigate these risks as much as possible.

The project involves members of DUBC (Dundee University Boxing Club) as well as fellow fourth-year students enrolled in BSc (Hons) Applied Computing at the University of Dundee. The Ethical approval enables participants to perform in a User-Centered Design (UCD) method of evaluation and fill out a NASA-TLX survey to convey an evaluation of the system.

1.4 Project Overview

The aims of the project were conducted through investigating many sources of similar products and papers to gauge what some key features and requirements to users may be, as well as to gain design inspiration and assess flaws in order to avoid them. Before development commenced, user testing was conducted to form prioritised features and designs. Through this, the project followed a pseudo-agile methodology, in that changes of devices and features were made throughout development. A sprint backlog, user stories and Gantt chart were implemented, but loosely regulated.

This paper proceeds by evaluating the usability and accuracy of the product, through analysing the results from user testing and the satisfaction of the users through a google form created questionnaire and NASA-TLX form. This progresses onto stating the success and description of the final product, followed by critical appraisal and analysis of the developer.

The remaining sections of the paper present a summary of the aims, features and designs assessed, with reflection of the development of the project, followed by recommendations of features, enhancements and changes the developer would want to see come to fruition in the future of the product.

2 Background

2.1 Motivation

HBO's "CompuBox" introduces the idea of sensors in sport and how they're used in competitive boxing. This has gained the attention of people and through the system has providing development of an automated scoring system for boxing, as seen developed by A.G. Hahn et al [3], but that doesn't help everyday users or even competitive boxers while they're training. The CompuBox is not accessible for everyday users, but there is a need for an accessible system similar to CompuBox to enable coaches, and users that are training to gauge how they are doing with every session to maximise the efficiency of each training session, to work towards reaching their goals.

Currently coaches can use manual clickers to count all of the punches thrown by their fighters. Coach Trepanier is quoted saying "I was using a manual clicker to count all of the punches thrown by my fighters. But doing so was very tedious and it made it much harder for me to focus on my fighter's strategy." [4]. This emphasises that having a system that shows how many punches a user has thrown can be beneficial to coaches.

2.2 Available Products

To conduct research, three similar products/papers available were analysed to generate ideas and evaluate methods already implemented, to assist the task of developing a boxing performance tracker. Three specific products were recognised as the main players as reinforced by Justin Perkins [5]; Hykso Punch Trackers, StrikeTec and Corner, as well as multiple research papers. A comparison of the three available products can be viewed in Table 1.

2.2.1

Hykso Punch Trackers

The Hykso Punch Trackers [6] allow live feedback, of punches and boxing statistics meaning in between rounds coaches or users themselves can see if the user needs to push or improve. This is done through viewing the punch velocity, intensity and determining which punches are being thrown in real-time.

Hykso also allows users to log the drills completed regularly and track progression over time. This allows comparison of speed, punch count and intensity to other fighters to compare strengths and weaknesses.

This is achieved through viewing the volume of punches, punch Speed, Intensity Score and Punch Categories (Right Straight/Left Straight/Left Power/Right Power).

Hykso removes motions they don't consider punches as much as possible, such as Blocks, Parries (hitting a punch coming towards you away), and skipping rope etc.

With Hykso you are able to extract 10 hours of use. All these features come with a price tag of £108, which as some reviewers claim, is expensive and may not be an ideal price for many amateur boxers and boxing enthusiasts [Appendix E: Available Products].

2.2.2 StrikeTec

The StrikeTec [7] virtual boxing coach analyses your punches while you're training, this allows you to track progress as well as enhance your abilities through an interactive dashboard and through tutorials available on their app.

One distinguishing feature of this product is the “Leaderboards and challenges” element. This allows users to compete against friends and other users all over the world. Competing with other people as well as completing weekly challenges allow users to push themselves and adapt to new methods of training constantly over time.

With StrikeTec 10 - 12 hours of overall battery life is claimed. However, all this comes with the biggest price tag of all products I viewed. To acquire the StrikeTec boxing sensors it will cost £180, which may be too expensive for many amateur boxers and boxing enthusiasts [Appendix E: Available Products].

2.2.3 Corner App

The Corner boxing app [8] and sensors work in real time to track and improve the hand speed, power, accuracy and overall performance of users. The app includes round times, trends in punches/combinations thrown and work rate analysis.

This is all done through two small sensors that are tucked under hand wraps when used to track/record.

The corner app sensors have a battery life of claimed 4hrs, which for one session is more than enough, however, that means sensors may require charging every day or two. Despite all the features the corner app is the cheapest of the three at £89.99 RRP but is only available through pre-order, shown in [Appendix X: Available Products].

2.2.4 Problems with the Boxing Trackers Available

One trend noticed throughout the three sensors looked into was all of them being relatively expensive, with the cheapest of the three being £89.99, shown in Table 1. Most enthusiasts or people curious in their boxing performance may find these too expensive, shown from reviews of the products in [Appendix E: Available Products]. With the system created in this paper, anyone using any device including ones they may already own, can upload raw accelerometer data to analyse their boxing performance. The price also reflects as being expensive when compared to other fitness trackers currently available on the market, for example the Misfit Shine 2 which costs £48 from Amazon [Appendix G: Misfit Shine].

Name	Price	Estimated Usage	Special Feature
Hykso Punch Tracker	£108	10 Hours	Save Workouts
StrikeTec	£180	10 - 12 Hours	Leaderboard System
Corner Boxing	£89.99	4 Hours	N/A

Table 1 [Comparison of Available Products]

Another trend noticed was that on the dashboard pages available, there were many graphs and figures, enough to overwhelm a user at a first glance, each having at least 3 graphs and counters just on the dashboard page. One method to combat this would be to have tabs, one for punches thrown, one for calories, one for trends, one for intensity and so on. If a user wishes to see all on one page they could have an “Overall” tab to allow them to compare each section. It was believed that this would make it simpler and would stick to the basics of measuring performance, instead of having to spend time deciphering graphs or charts. [Appendix E: Available Products]

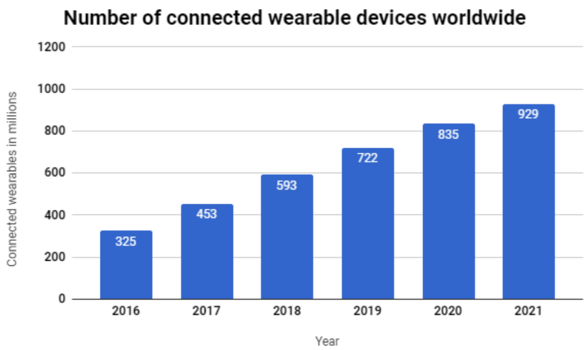
Another issue was the battery life with each of the devices, with the longest of the three having 10-12 hrs of use. The GENEActiv Original, used in this project has considerably longer battery life, with recording at 10 Hz for 45 days and 100Hz for 7 days is possible, even though it has the same charging method, of charging the battery after use.

Many of the devices aim to assist users by giving advice, but none of the devices take into account the fighting style of a user, i.e. Philly shell defence. The Philly shell defence suggests one of your arms is lowered to prevent your arm obscuring your field of vision, however, this style may make the system believe that the user isn't using that arm efficiently.

Lastly, all the devices are designed to work with the one app provided, the raw data cannot be extracted for you to then upload into other applications to track performance.

2.3 Related Work

As use of fitness tracker, health monitors and wearable technology in general continues to grow, the advancements of technology follows. With the implementation and evaluation of connected wearable devices being at the highest level ever seen, and is predicted to continue growing, shown in [Figure 1]. The developer aims to be at the forefront with a system that allows for the data from all devices to be used with the system. With 453 Million people connected to wearable devices in 2017, this shows a formidable increase on 2016's 325 Million, as can be seen in [Figure 1] below.



[Figure 1: Number of connected and predicted to be connected, wearable devices, from 2016 to 2021[9]]

The system is developed to include the number of punches and the acceleration of the punches thrown. In the field of sensors and sensors in sport, Chambers [10], discusses and reviews how microsensors are used to detect sport-specific movements in a wide range of sports. The ability to capture the sport-specific movements emphasises the capability of the technology to provide details on the user's performance. This is method of recording and giving details of user performance is also conducted by Ed H. Chi [11], who discusses and evaluates the collaborative effort to develop and introduce sensor technology for the environment of martial arts sparring. The system similarly uses force sensors attached to the body protectors to assist judges and referees score matches. The overall premise is the same as previously discussed "CompuBox" [1] in boxing, where both have objectives for the technology, to support judges in accurately scoring matches. This provides methods and direction towards a system to evaluate performance of the user.

Due to the system being specific to the sport of boxing, analysis and research of papers conducting testing and implementation of boxing was explored. For example Mark Wooster et al[12], worked on conducting testing and implementation to invent a method for quantifying impact forces in a boxing match in real-time, through transmitting impact force data from each glove within the boxing match to a remote receiver. Data can be collected from the strike force generated, assessment of the statistics of the strike force data from each boxer, during a round or cumulatively during a match, to compare one boxer to another. Similarly, Matthew Klapman[13] provides a boxing glove impact measuring system, where the accelerometer is within the boxing glove body, like with Wooster et al, to measure the force of impact, but in Klapman's case it is to measure both the instantaneous acceleration and the force of impact of the boxing glove. This gave ideas to develop a system that can collect the data from the acceleration and force of the punches generated.

As the system was designed for boxing, the use of wireless technology was of great significance due to the risks of athletes making movements to cause the cables to intertwine or restrict movement. In general wireless technology is prevalent in combat sports, predominantly due to the movement athletes make, where having cables could be hazardous. For this reason many projects and products incorporate wireless technology. The developer aimed to produce a system that analysed users' performance post match or training through using wireless technology, however through research found that the paper, "A wireless-sensor scoring and training system for combative sports" by Kane Partridge et al [14], describes an electronic system for use primarily in the sport of boxing. This shows technologies very similar to the products available on the market such as "Hykso"[6], which gives the developer inspiration to integrate sensors on athlete's hands, through a wireless network, to monitor physical contact in either real-time or post event through a remote computer to determine punches, which then derives measuring scores and final outcomes, on top of analysing an athlete's performance post match or training session.

2.4 Summary of Related Work

Through the literature and research papers analysed, it was evident that for a boxing performance tracker, there are methods for recording and displaying the measurement of punches, from speed/velocity to power/force of punches.

From the literature and research papers analysed, as well as a user-driven study to gather requirement of the system, found in [Appendix H: User Testing Results] A foundation of what features and functionality should be implemented was found.

2.5 Alternative Accelerometers

The developer was able obtain three off-the-shelf activity tracker, from a member of staff at the QMB, University of Dundee. The three being a Misfit Shine, Fitbit Charge HR and a GENEActiv Original

2.5.1 Misfit Shine

The Misfit Shine, shown in [Figure 2] allows you to set your own goals, as well as giving you a platform to see your progress, through measuring different activities such as swimming, cycling, running, walking, while studying the steps, distance, and calories burned in these exercises. Then at night, the Misfit Shine can analyse your light and heavy sleeping patterns/times.

The Misfit Shine is different in that there are no buttons, no cables, no charging, the device is powered by a removable 3V Lithium Coin Cell. This gives a claimed battery life of up to 6 months, however, after 6 days of use, the app recommended I replaced the battery as it was low, shown in [Appendix: Sensor 3: Misfit Shine]. As the Misfit Shine has no buttons, you cannot view any data or progress other than the LED progress dots on the device, without having to synchronise with the dedicated Misfit App.

The Misfit Shine is claimed to have a strong build to last a lifetime, and it was wearable: a tiny all-metal disc.
The developer believed it would be an ideal device for developing a boxing performance tracker, however many reviewers dispute this and claim it only works for a few months before breaking. Reviews and recorded use with the Misfit Shine can be found in [Appendix: Sensor 3: Misfit Shine].

Figure 2: Misfit Shine

2.5.2 Fitbit Charge HR

Fitbit Charge HR, shown in [Figure 3] is very similar to the Misfit Shine in that it allows you to set your own goals, and see progress by synchronizing the device with integrated app provided to see your progress and statistics, through measuring different activities such as swimming, cycling, running, walking, while studying the steps, distance, calories burned in these exercises. Then at night just like the Misfit Shine, the Fitbit Charge HR can analyse your sleeping patterns/times.

Unlike the Shine, the Fitbit Charge HR offers automatic, continuous heart rate and activity tracking. The device allows users to cycle through different options such as calories burned, steps taken, heart rate and more, by pressing the one button on the device. This means, unlike the Misfit Shine you can view some progress and statistics without having to synchronise the device to the dedicated Fitbit App on the user's phone. However, in my experience, the device was extremely unforgettable, due to its design and build quality. The experience of using the device and reviews with the device can be found in [Sensor 3: Fitbit Charge HR].

Figure 3: Fitbit Charge HR

2.5.3 GENEActiv Original

The GENEActiv Original [Figure 4], was the only GENEActiv device available out of the four GENEActiv products. It is designed to allow the extraction of raw data output including 3 axes used for physical activity. The GENEActiv are water/sweat resistant devices with strong/robust build quality. The GENEActiv Original allows for continuous raw data recording of up to 45 days at a frequency of 10Hz and 7 days at 100Hz, through it’s simple on/off button on the centre of the device.

As the GENEActiv comes with the availability of raw accelerometer data extraction and a desktop app, it is used for conducting research and testing purposes [15]. GENEActiv is recommended for a vast array of applications such as epidemiology, public health, exercise interventions and in my case, physical activity. The device can be used for all age groups from children through to the elderly [16].

Figure 4: GENEActiv Original

3 Specification

Currently, there doesn't appear to be an available system or application that provides users with the option to upload raw accelerometer data recorded from alternative devices other than from the one the system is designed for. This system is developed to allow anyone using any device including ones they may already own, to upload raw accelerometer data to analyse their boxing performance.

Through the products studied, it was found that websites/applications only work with devices provided. One example is the data recorded from the Hyksos sensors will only be visible and displayed through the Hykso application/website. The system in this project aims to be in the form of a website that allows CSV files with recorded accelerometer data from any device to be uploaded and analysed.

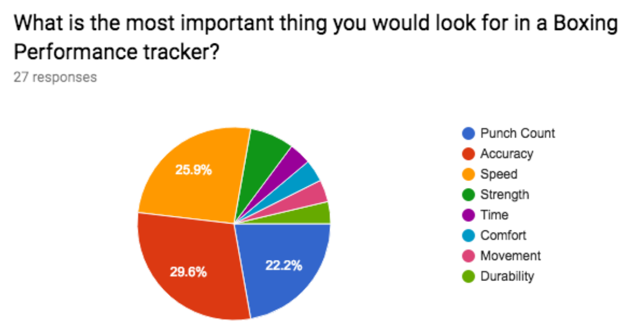
With the user group, amateur boxers being the target user group for the development of this project, since current devices are shown to be out of a comfortable price range for the practicing amateur boxers and enthusiasts, the system was developed with them in mind, to allow accessibility and catering for all users.

Another trend noticed on each of the product's dashboard pages available was that there were many graphs and figures [Appendix E: Available Products], enough to overwhelm a user at a glance, each having multiple graphs and counters just on the dashboard page. One method to combat this would be to have separate tabs/cards/sections for punches thrown, one for calories, one for trends, one for intensity and so on. If a user wishes to see all on one page they could have an "Overview" tab to allow them to compare each section. The developer believes this would make it simpler as users can take a quick glance to find and know the number of punches, instead of having to spend time deciphering graphs or charts.

3.1 Studies

As this this system follows user-centered design, in order to gather requirements, two studies were conducted. The first being a study on current products available and reviews for current or previous users of the system, to highlight areas that should be considered throughout development. This can be found in [Appendix E: Available Products].

The second study being a user-driven study was before any implementation, a user survey was conducted to explore potential features users would want from a boxing performance tracker. This was executed through a Google form created by the developer then distributed to friends and fellow members of the Dundee University Boxing Club, via invitation through social media, where 27 participants, aged 19 to 35 with varying years of experience in the field of boxing, gave their opinion on what features they wanted [Figure 5]. Details of user testing can be found in [Appendix H - User Testing].



[Figure 5: User Wants: Top 3 being Accuracy, Speed and Punch count]

3.2 Methodology

A pseudo-agile with an iterative development cycle method was adopted in this project, where tasks were set and completed in bursts, which allows for some changes as seen with the transition from mobile app to a website, but deadlines that were emplaced were loosely followed.

3.2.1 Product Backlog

A product backlog was created to aid the developer in laying out all the content that needed to be completed for the project. The document includes the list of features the system should include, as well as containing short descriptions of all the functionality desired in the product. This was applied to allow the most important and least time consuming features to be added in first. The product backlog can be found in [Appendix C2: Product Backlog]

In conjunction with the product backlog, user stories were created. A User story is a tool used in the agile software development methodology to obtain a description of the software features in the perspective of an end-user. A user story includes a small description, the priority and complexity of the features. User Stories can be found in [Appendix C1: User Stories].

3.2.2 Gantt Chart

A Gantt chart was created for this project to aid in planning and scheduling tasks throughout development. The Gantt chart is designed to help assess how long a project should take, plan the order in which tasks should be completed and determine the resources required to fulfil these tasks. The Gantt chart itself is a type of vertical bar chart that represents the project schedule. This includes but is not limited to showing progress, development tasks and timeframes. The Gantt chart can be viewed in [Appendix B: Gantt chart].

3.3 Implementation and Design Iteration

Cycles of testing and implementing were performed. After development concluded, an observational study was conducted with a variety of tasks, explorational activities and a think-aloud protocol, meaning participants were encouraged to communicate and conversate. From this user-centred study, a series of successes and some work for future development was documented.

This allowed for more freedom for working on different features when most deemed reasonable, for example implementing an "Average punch acceleration" graph after a "number of punches" graph, would not have seemed like a plausible transition when setting up the method of creating the system, however after creating the "number of punches" graph the method of doing so was very similar and enabled me to quickly implement the "Average punch acceleration" graph.

A formative evaluation method was decided, where the users are surveyed before development to gather user-wants and then towards the concluding chapters of the project, a summative evaluation method was employed. In the summative evaluation, participants were asked to complete a series of tests. Throughout testing, participants were prompted to give their thoughts and any critical analysis of the product as it was. Through the qualitative feedback and NASA-TLX forums evaluation and enhancement of the project was brought to fruition. The measuring instruments being in the form of tasks to assess performance and surveys/questionnaires which were created using Google forms, as it allows for the data to be collected, anonymised and formed into graphs in an ethical manner. All relevant testing and evaluation materials can be found in [Appendix: for Google forms].

4 Design

4.1 Design Decisions

Throughout development decisions were made to edit, enhance or remove implemented work in the system. These decisions were changed from suggestions on user feedback and self-evaluation of the system.

4.1.1 Original Plan

The first attempt at making a boxing performance tracker by the developer was via a cross-platform mobile application that connects to an Accelerometer via built-in Bluetooth.

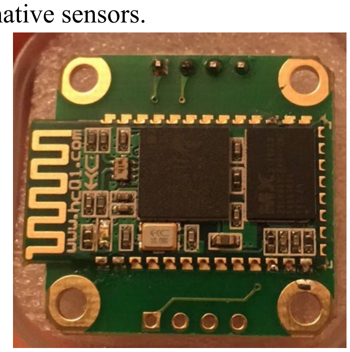
4.1.2 Cordova

As this was my first attempt at mobile app development I researched the most advantageous programs and software to use by asking peers and researching online. I found many available software and systems to choose from, for example, Xamarin, Ionic, Cordova etcetera.

Cordova was decided over the rivalling software predominantly due to the tutorials for Cordova being available on Lynda.com and hearing good reviews/comments about the software both in person and online.

4.1.3 BJY61 Accelerometer

The first Accelerometer device in development was the BJY61 Bluetooth MPU6050 module angle output 6-axis Accelerometer Gyroscope BWT61, shown in [Figure 6]. The MPU6050 module worked well through a serial connection, using Arduino as the software to program the module. However due to its unstable nature and lack of fully functioning Bluetooth connectivity (worked through serial but that meant there would be the hazard of wires with boxing/punching). The decision was made to use alternative sensors.



[Figure 6: BWT61 Bluetooth MPU6050 module]

4.1.4 Android Studio

Android was one of the mobile operating systems that the project was aimed. As Cordova was being used for mobile app development, emulators were required to be called by Cordova. However throughout development with Android Studio many issues occurred with the emulators, libraries for the Bluetooth accelerometer module and Android studios build tool “Gradle”. Due to a MacBook Pro being used for development thus far, a Windows PC was acquired yet fell into the same issues. After much deliberation, the decision was made to use an off-the-shelf robust wireless measurement device with direct access to the raw data.

Through Dr Iain Murray, a member of staff at the University of Dundee, a Misfit Shine, GENEActiv Original and a Fitbit Charge HR was obtained.

4.1.5 Choosing GENEActiv over the Misfit and Fitbit

The GENEActiv Original was selected as the main device for the development and testing of this project because it was the easiest to extract and read raw data from. The device also felt the most durable and robust overall, with the Fitbit easily being the least durable and comfortable.

The GENEActiv Original has a simple on/off button system, which allows for users to easily pick up and use. This means there was a smooth learning curve for people using the device. The GENEActiv Original holds many advantages, for example, the GENEActiv Original has a longer battery life shown through being able to record at 10 Hz for 45 days and 100Hz for 7 days. Both the Misfit Shine and Fitbit Charge HR were tested for battery life and both required charge/replaced battery in under a week. [Appendix G - Sensor 4: GeneActiv Original]

Just like the Fitbit Charge HR, the GENEActiv Original is water resistant (and sweat resistant) which is sufficient for boxing training, as users will most likely sweat but not be submerged in liquid. Since GENEActiv is like a watch, it can be securely strapped around a user’s wrist to allow any boxing, including shadow boxing (i.e. no gloves or hand wraps need to be on) anywhere, anytime, this is one advantage over the products already available on the market - they are sensors that need to be covered/secured with the hand wrap or glove.

The GENEActiv Original comes with a simple charging station that allows multiple GENEActiv Original devices to be charged at once. This makes it extremely easy for day to day use as wrist placement is preferred area for recording, stated by Stuart J. Fairclough et al [17], on top of its ability to record frequencies ranging from 10–100 Hz and can collect data for up to 7 days at 100Hz, which Christine A. Schaefer et al, also found advantageous for research in their paper [18].

GENEActiv allowed the device to be placed into the compatible charging station for both charging and the extraction of the raw data, which made it efficient for both viewing results and testing purposes for the developer.

Features	GENEActiv Original	Fitbit Charge HR	Misfit Shine
Easy to Extract Raw Data	✓	X	X
Start/Stop button	✓	X	X
Battery life	**7 - 45 Days**	**3-4 Days**	**6 days**
Water/sweat resistant	✓	✓	✓
Charging dock/station	✓	X	X
No Screen (no cracking if striked/ dropped)	✓	X	✓
Desktop app	✓	X	X

Table 2 [Comparing the sensors]

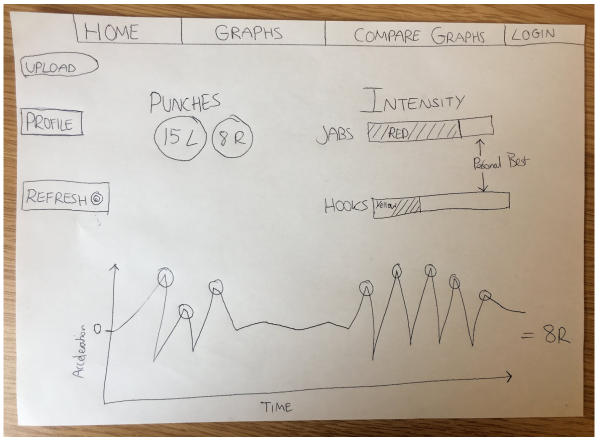
4.2 Design Method

The design method adopted by the developer was a user-centered design. As the methodology being followed was pseudo-agile, throughout development the interface of the system was continually enhanced by following responses in user testing and questionnaires to implement what users would want, which can be seen in [Appendix H - User Testing]. Through doing so users were asked and prompted to give suggestions and preferences on the design, style or layout of the system. The interface received positive responses from the users of the final user testing conducted.

4.2.1 Prototypes

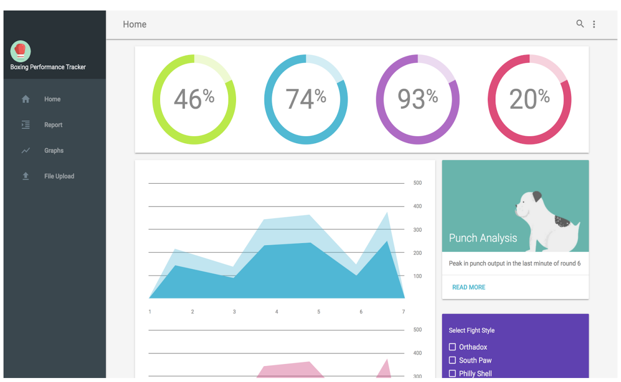
In early stages of designing, two prototypes were designed to provide an early sample and model to base the design of system during implementation, one being low fidelity [Figure 7] and the other high fidelity [Figure 8].

The low fidelity prototype was designed to allow brainstorming and draw designs/ideas to spark more designs. From the many sketches drawn, the concluding sketch, shown below [Figure 7] was selected.



[Figure 7: Low Fidelity: Paper Sketch]

From the low fidelity prototype sketch, the high fidelity prototype, which consisted of an Electronic HTML Prototype created using MDL Dashboard Template [Appendix F: Prototypes]. By creating the Electronic prototype with HTML, it provided initial practice with HTML coding language for implementing the system later on.



[Figure 8: High fidelity: HTML Dashboard page]

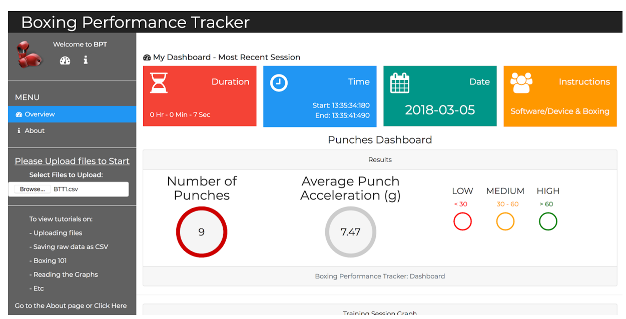
4.3 Design Process

In my first iteration of creating an app, "MIT App Inventor" was used, however after research and a small amount of time playing with the software I rendered impractical for my project as "MIT App Inventor" was a visual programming environment designed to help everyone, including children and beginners to build apps, the conclusion was rendered that it would have many limitations and may not be powerful enough for handling large amounts of accelerometer data [19].

The design from the original prototypes was iterated upon from information gathered from user testing to continuously enhance the interface. Through the user testing conducted, the bottom interface was chosen based on majority decision through user testing as can be seen below. Screenshots of the interfaces throughout development can be found in [Appendix H - User Testing].

Through the many iterations and feedback from testing, the final interface was formed. As one of the aims was to make the interface user friendly, colourful information cards were introduced to make the website more visually pleasing and also to provide information of the session; this design choice was responded to with positive reinforcement from user testing.

The final design is also loosely based on the high fidelity prototype, as both make use of circular graphs and implement a multi-coloured colour scheme that can be seen below [Figure 9]. This was chosen as the usability, ease of use and learnability of the system showed positive responses from the testing conducted. [Appendix H: User Testing Results]



[Figure 9: Dashboard]

4.4 Technologies Used

Throughout development, many tools and languages were used, in which each provides functionality and executes a specific task. In this section, the use of these technologies will be outlined and some alternatives will be reviewed and summarised as to why they were not used.

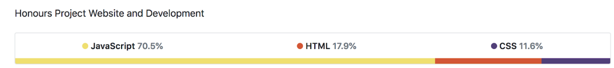
4.4.1 Git & GitHub
Git is a version control system used for tracking and monitoring changes in computer files, in my case, source code of the software being developed. Git also coordinates work on the files among multiple people, allowing for multiple files to be worked on, viewed and changed. GitHub is a free and open service for online repositories. GitHub is used globally for web-based hosting and version control using git. GitHub offers version control and source code management as well as having code reviewing, managing projects and access to feedback from other developers.

Git/GitHub is continuously used in this project to safely store implemented code, as well as provide other advantages such as showing details of changes in the work committed by the developer, providing a backup of the source code and allows the reversal of changes, should there be mistakes made. To commit code is to save the changes made in the source code into Git/GitHub [20].

4.4.2 Visual Studio Code
Visual studio is a source code editor developed by Microsoft for Windows, Linux and macOS. VS includes support for debugging, embedded Git control, syntax highlighting, intelligent code completion, snippets and code refactoring. This software was chosen over NetBeans and Atom as the developer had previous experience with visual studio, and visual studio code is a relatively new software, therefore benefits from the latest technologies, on top of which visual studio is lightweight and designed for web development, including but not limited to all the languages used in this project.

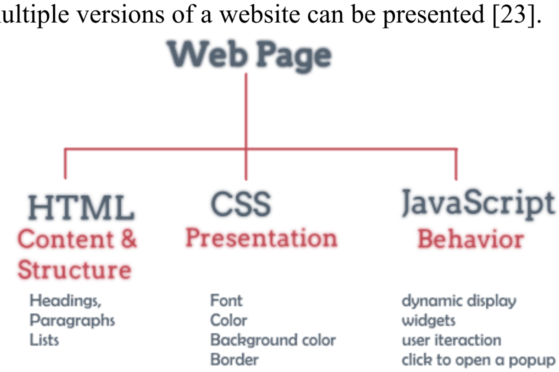
4.4.3 HTML
For creating and structuring web pages and web application, HTML (Hypertext Markup Language) is the standard markup language. HTML allows the user to navigate from page to page, through for example, hyperlinks and buttons clicked. Along with CSS and JavaScript, it forms the foundation for technologies for the World Wide Web [Figure 11]. HTML works by creating the structure and content of a webpage through web browsers receiving the HTML documents from a web server or local storage to render the documents into multimedia web pages, for example defining paragraphs, headings, data tables or embedding images/video content in the page [21].

4.4.4 JavaScript
JavaScript (JS) is a high-level, scripting/programming language that allows for dynamically updating content, controlling multimedia, animating images, and much more, through implementing complex tasks on web pages, for example, content updates, interactive materials such as graphs and maps, animated 2D/3D graphics etc [22]. JavaScript was chosen over typescript by the developer due to having experience with the language and believing there are more resources available for JavaScript. JavaScript made up for most of the code [10].



[Figure 10: JavaScript, CSS and HTML % in code]

4.4.5 CSS
CSS (Cascading Style Sheets) is a style sheet language used for describing the presentation and visual appearance style of a document written in a markup language such as HTML in this project. The CSS language is the style rules that are applied to the HTML content, for example, setting the text font style throughout the page or changing the colour of the background [21]. CSS comes with many advantages, one of which being that it saves time, as you can write a CSS file once and reuse the same sheet throughout multiple HTML files and define the style for each HTML element. This means if you make a change to the CSS file, it automatically updates all the HTML files making use of the CSS sheet. Another advantage of CSS is that it is compatible with multiple devices, the style sheets allow the content to be optimised for more than one type of device, through using the same HTML document, multiple versions of a website can be presented [23].



[Figure 11: HTML, CSS & JavaScript Diagram [21]]

4.4.6 Bootstrap and W3Schools
Bootstrap is a free and open-source front-end library for designing websites and web applications. It contains HTML- and CSS-based design templates for typography, forms, buttons, navigation and other [24]. Bootstrap allows for responsive, mobile-first projects to be built on the web.

W3Schools is a popular website for learning web technologies, though tutorials, examples and temples. The website includes content for JavaScript, JSON, Bootstrap, PHP, HTML, SQL, CSS and much more.

The web page in this system is predominantly made up using W3Schools “Analytics” template and Bootstrap’s “Navbar” template.

4.4.7 Grunt

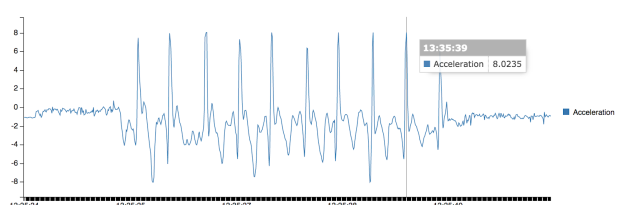
Grunt was used as the JavaScript task runner. The tool is used to automatically perform frequent tasks such as minification which is the process of removing all unnecessary characters from source code without changing its functionality, compilation, unit testing and linting. In the case of this system, the developer made use of grunt to automate minification of code and compilation. Grunt also publishes plugins that also many tasks to be completed instead of having to write the code.

4.4.8 Browserify

Browserify is an open-source JavaScript tool that allows developers to write Node.js-style modules that compile for use in the browser [25]. Since browsers do not have a method called “require” defined, and Node.js does, Browserify allows code to be written that uses "require" in the same way that would be used in node. Therefore the developer made use of Browserify to include the “require” module to then implement a JavaScript time series spike detection API called “Slayer” for Node.js and in this case, the browser.

4.4.9 C3.JS & D3.JS

Both C3.js and D3.js was implemented into the system to provide visualisation of the uploaded data in the form of an interactive line/timeline graph, can be seen below in [Figure 12]. C3 is a D3 based reusable chart library that enables further customisation for web applications. D3 is a JavaScript library used to produce dynamic, visually pleasing and interactive graphs in web browsers.



[Figure 12: Line Graph]

4.4.10 NPM

NPM was used as the package manager for the JavaScript programming language, it enabled the discovery and use of libraries/plugins such as “Slayer” to be utilised throughout development.

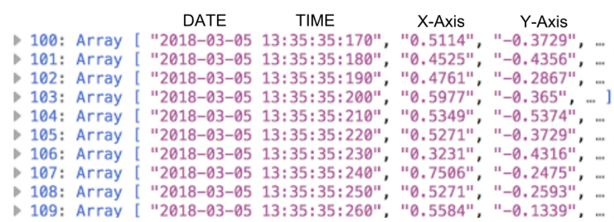
5 Implementation and Testing

5.1 Main Tasks

As stated, Visual Studio code was the integrated development environment (IDE) of choice, with the languages: HTML, JavaScript and CSS. Through using these languages and compatible libraries/plugins, most main aims and objectives were implemented.

5.1.1 Parsing using PapaParse

The first major task that was implemented into the system was being able to pass in the raw data collected from the GENEActiv. As the GENEActiv allows users to save the data as a CSV file, this process seemed most logical to follow. This was a new area as developer had never dealt with CSV files or raw accelerometer data, however through research online stumbled upon PapaParse [26]. PapaParse allows the CSV data to be read and performs a transformation into a structured set of rules (for example removing commas or empty lines in the file) to extract the data represented by each line in the file. To appropriately make use of the uploaded raw accelerometer data, PapaParse quickly and safely parses the data into 3 columns, Date, X axis and Y axis [Figure 13]. This is used throughout the system for example the date column is used to populate the “duration”, “Time” and Date cards on the Dashboard.



```
DATE TIME X-Axis Y-Axis
▶ 100: Array [ "2018-03-05 13:35:35:170", "0.5114", "-0.3729", … ]
▶ 101: Array [ "2018-03-05 13:35:35:180", "0.4525", "-0.4356", … ]
▶ 102: Array [ "2018-03-05 13:35:35:190", "0.4761", "-0.2867", … ]
▶ 103: Array [ "2018-03-05 13:35:35:200", "0.5977", "-0.365", … ]
▶ 104: Array [ "2018-03-05 13:35:35:210", "0.5349", "-0.5374", … ]
▶ 105: Array [ "2018-03-05 13:35:35:220", "0.5271", "-0.3729", … ]
▶ 106: Array [ "2018-03-05 13:35:35:230", "0.3231", "-0.4316", … ]
▶ 107: Array [ "2018-03-05 13:35:35:240", "0.7506", "-0.2475", … ]
▶ 108: Array [ "2018-03-05 13:35:35:250", "0.5271", "-0.2593", … ]
▶ 109: Array [ "2018-03-05 13:35:35:260", "0.5584", "-0.1339", … ]
```

[Figure 13: Screenshot of results of Parsed CSV file]

5.1.2 Creating Line Graphs

After parsing the data correctly, the developer felt a displaying a graph representing the acceleration throughout the session would be the next step. To create an interactive line graph being displayed through the raw accelerometer uploaded, the data parsed into a format that is easily readable and converted, gets manipulated by C3JS and D3JS in the JavaScript file to display interactive line graphs. As seen previously in [Figure 12].

5.1.3 Finding the Peaks

To calculate the punches thrown, first the peaks in acceleration which represent a punch must be found. To do so, the spikes/peaks in a chart has to be calculated, a peak or spike in a time series is the highest value before the trend starts to decrease. As this task would take a large portion of development to implement by an individual, the developer decided to use an API called "Slayer". This is a key function in the project as it identifies sudden increases of acceleration, that represents a user's arm extending to accelerate then retracting to accelerate, which can be concluded as a punch. Code is shown below in [Figure 14].

```
//Find Peaks in the Graph
var slayer = require('slayer');
var arrayData = yLabel;

slayer({ minPeakDistance: 1, minPeakHeight: 7}).fromArray(arrayData).then(spikes => {
```

[Figure 14: Slayer]

5.1.4 Finding Punches

The main pioneering feature of the boxing performance tracker in this project is to identify "Punches" as it is the main tool used in the sport of boxing. From this other features can be derived or built on top of, for example, speed, power and type of punches. In order to identify punches, the spikes/peaks found from "Slayer" is then checked to be above a certain level of acceleration to represent a punch. This is incremented into a counter that adds 1 every time a punch is found, which in the end is displayed as an integer, as can be seen below in [Figure 15].

```
//for loop to detect punches ie acceleration above 5
var realPunches = 0;

for (var i = 0; i < spikes.length; i++) {
    if (spikes[i].y > 5) {
        realPunches++;
```

[Figure 15: Finding Punches]

From the value collected, data visualization was emplaced, in that if the integer that represents the number of punches was below 30 it will be displayed in a red circular graph [Figure 16], between 31 and 59 it would be orange [Figure 16] or above 60 it would be green [Figure 16]. This is used to give some instant information to the user, for example if it is green it means the user threw a lot of punches, or completed a longer training session, whereas red would imply the number of punches was slow or the session wasn't long. Through looking at the graph this can be relayed. The circular graph is displayed with the surrounding rim of the circle being the appropriate colour to the number of punches thrown, with the text being black. However the graph is interactive, where if you hover over the graph it enlargers the displayed number and changes the colour to the appropriate colour scheme, as can be seen in Figure X & X. The circular graphs were modified from Andre Firchow percentage circle [28].

[Figure 16: Circular Graphs]

5.1.5 Finding the Average Acceleration of Punches

After finding the number of punches in a session, finding the average acceleration of those punches was the next task. The acceleration of a punch translates to the speed of which the users arm extends to throw a punch. This completed by using Slayer again to find all punches and dividing it by the acceleration amount of all the punches, shown in [Figure 17]. For example if two punches are thrown that total give the acceleration of 16 is divided by the number of punches thrown, in this case 2, that gives the result of the average punch acceleration being 8g.

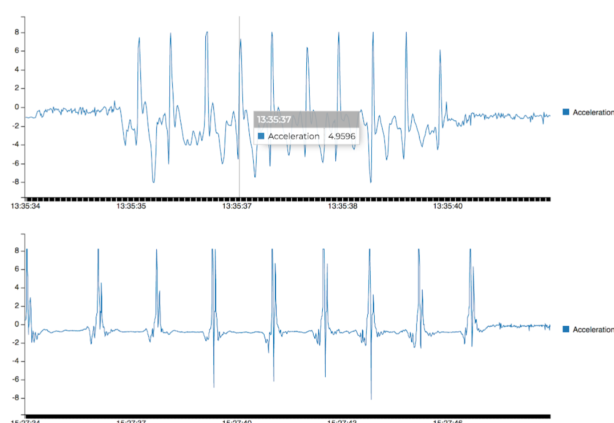
```
//for loop to detect acceleration above 5G
var gAccelerationAmount = 0;
var numberOfRealPunches = 0;

for (var i = 0; i < spikes.length; i++) {
    if (spikes[i].y > 5) {
        numberOfRealPunches++
        gAccelerationAmount += Number(spikes[i].y);
    }
} var avg = gAccelerationAmount/numberOfRealPunches;
```

[Figure 17: Finding Average Acceleration]

5.1.6 Comparing Sessions

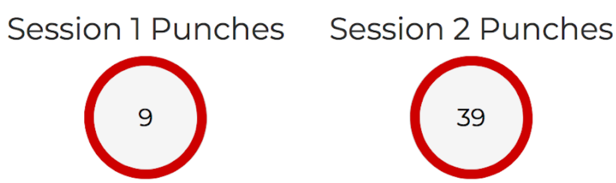
In order for boxing performance tracker to show progression or improvement of the user, the system must allow for sessions to be compared. One main comparison would be to compare the actual graphs of the session to allow the users to easily identify the differences of the workout was. For example in [Figure 18] the top graph clearly shows the user wasn't moving at the start then threw a burst of punches, whereas the bottom graph shows continuous punching at an interval rate. This was tested to be obvious for users through user testing, the user testing reinforced through user testing.



[Figure 18: Comparing Line Graphs]

Another method of comparing two sessions is to compare the statistics of the sessions through the number of punches thrown and average punch acceleration.

Displaying the number punches for each session was implemented as can be seen below [Figure 18]. However in [Figure 18] the results of the second graph show that the surrounding colour of the circle should be orange, this requires enhancement as the colour of the second session circular graph displays the colour corresponding to results of the first session.

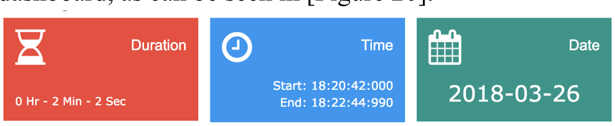


[Figure 19]

On top of being able to view the number of punches, average acceleration and the line graphs, a session could be compared using the session statistics such as the duration, time or date. For example if a user knows they completed a session after work on one day, that will show decreased performance compared to a day the user did not have work.

5.1.7 Statistics/Information of Session

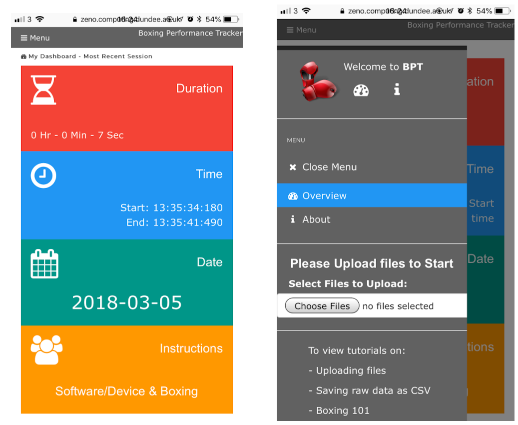
To make the session information more obvious to the user, information cards at the top of the dashboard was implemented. This was designed to allow the user easily understand some details and information of the session uploaded, so they know the duration, time and date. This is achieved through displaying information cards on the dashboard, as can be seen in [Figure 20].



[Figure 20: Dashboard]

To get time the first and last element from the date column in the parsed file was selected to be displayed in the "Time" card. .

Designing the system to be user friendly was a task that was predominantly implemented. Through using w3schools "Analytic" cards, for the information to be displayed in a format easily readable on mobile/small screen devices. As a result of this the Menu and sidebar was also altered using Bootstrap to implement a version of the system suitable for mobile/small screen devices, as can be seen below with the website being viewed on an iPhone 6S [Figure 21].



[Figure 21: Website on Mobile]

5.2 Hosting the Project

Local hosts are used to allow users to view their code in a browser, in the way it would look if it was deployed. In this case the HTML, JavaScript and CSS files were locally hosted using Python to run a simple local HTTP server to allow the developer to see the files as they were being developed on a browser throughout development.

In order to view the project online on the World Wide Web, the files were deployed and hosted through zeno.computing, which is the University of Dundee's hosting platform.

5.3 Testing the Code

In order to view, deal with and analyse bugs, debugging was conducted throughout development. One method of debugging conducted was the use of console.log commands in the JavaScript files. This was predominantly used throughout development as it offered aid in where the problem is because the console.log command would be executed according to the structure of the code, for example if you put the console.log before and after a calculation and the console.log doesn't run the second time, it is known that there is an issue before the second console.log is completed.

Another method of testing the implemented system is to run the code on a browser. In the developers case both Mozilla Firefox Quantum and Google Chrome Browsers was used. This was beneficial due to the inspector tool being able to flags issues, potential errors and bugs. While the errors/bugs were highlighted the inspector included suggestions as to why there is an issue and in what line/file the issues were in.

5.4 Issues with Slayer

It was found late into the project that the API "Slayer" produced inaccurate results for the number of punches. However through GitHub, this issue was communicated with the developer of Slayer, in which they responded by with suggestions which were rendered futile after many attempt and eventually claimed there was a bug in his code, which prevented this project to accurately calculate the number of punches thrown in a session. For example, if the user threw 10 punches, the system would claim 9 punches were thrown.

6 Evaluation

6.1 Usability Testing

Usability testing was an important element conducted throughout the project. Testing was conducted on fellow students and boxing practitioners at DUABC. This was because it provides a real-world use of the system and can highlight any issues, concerns or bugs people may find. The system followed a user-centred design, to provide a product with good usability and correctness. There were two main methods of user testing in this project.

The first was in the form of a google forum to gather user needs, features and requirements for the product. Snippet of the results from the questionnaire is shown above in [Figure 5]. Full document of user questions can be found in [Appendix H - User Testing].

The second was a form of Black-box testing, to assess the effectiveness of the system, its features and usability of the system implemented, through a think-aloud usability testing via three methods, questionnaire after testing and NASA-TLX forum to assess the success of the end product.

6.1.1 Tasks Performed

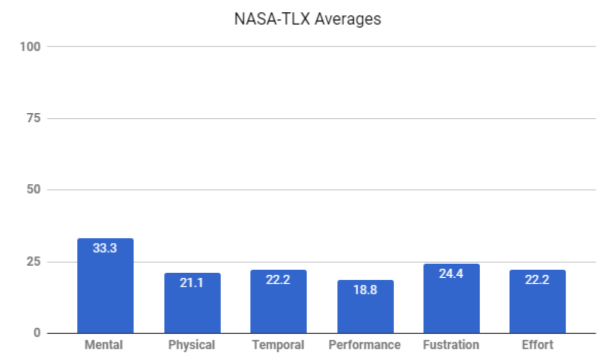
The test consisted of a set of tasks described in an A4 sheet given to the participant [Appendix H - User Testing]. Participants were set in a think-aloud environment and allowed an unguided exploration of the system to allow for as much freedom as possible, on top of being encouraged to talk about any issues, concerns or thoughts they had during testing. All results, issues and performance were recorded by the examiner during testing [Appendix H - User Testing].

6.1.2 Questionnaire/ System Usability Scale

Upon completion of the tasks, a questionnaire was presented for each participant to undertake in complete anonymity. The questionnaire is a modified System usability scale, where participants were asked to rank Appearance, Functionality, Features, Usability/Ease of us and overall out of 5. The questionnaire also contained questions to help enhance the system, find bugs and provide a section for additional comments.

6.1.3 NASA-TLX

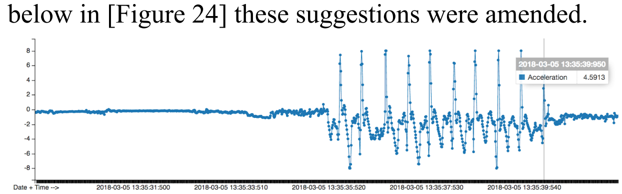
NASA-TLX is a widely used tool that provides subjective, multidimensional assessment of a task, performance or a system. The participants were given 6 scales to form the questionnaire. The scales were assessed from 1 to 10 with 1 being the lowest and 10 being the highest. This consisted of a rating on the Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration of the system. With the results shown below [Figure 22].



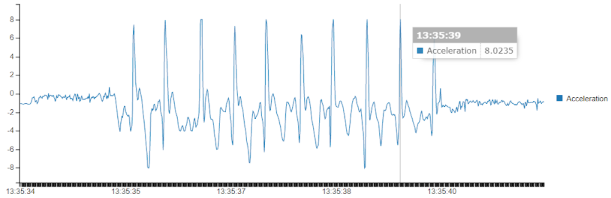
[Figure 22: NASA-TLX Results]

6.1.4 Participant Feedback

Overall the project received positive feedback relayed from the questionnaire and NASA-TLX forms completed after testing [Appendix H: User Testing Results]. The general consensus of the system was viewed in a positive outlook, these comments can be found in the [Appendix H: User Testing Results]. Participants also made some suggestions to enhance the system and expressed features they would like to see implemented. Some of the suggestions participants requested was brought to fruition, such as, the removal of the data points on the line graph [Figure 23], removal of the date label on the x-axis and disabling the ability to zoom into a graph, as this disables the user from scrolling up/down page when the cursor is hovering over the graph. As you can see below in [Figure 24] these suggestions were amended.



[Figure 23: Before user testing]

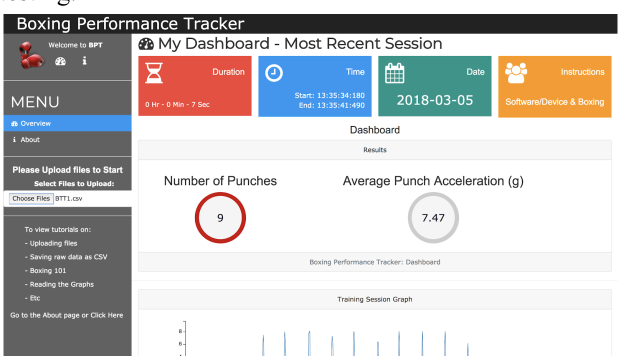


[Figure 24: After user testing]

7 Description of the Final Product

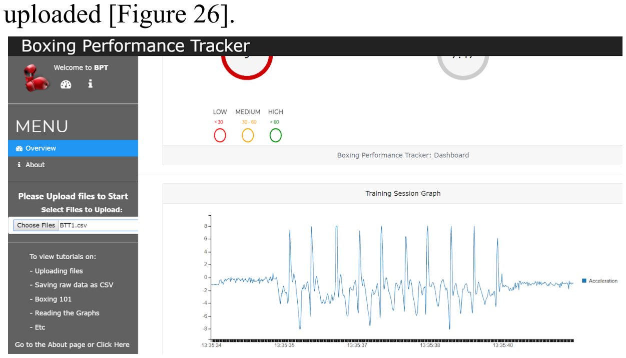
7.1 Overview Page

This page is where the main visualisation of the uploaded data is displayed. [Figure 25] The page consists of a dynamic title, a sidebar for users to navigate the website and upload files to be analysed and sections on the page. At the top is the dashboard which consists of four colourful cards that display the duration, time, date and link to the instructions page. The page was designed to prevent a user from being overwhelmed with information or having to decipher charts, therefore having less than three graphs proved a positive result, reinforced by user testing.



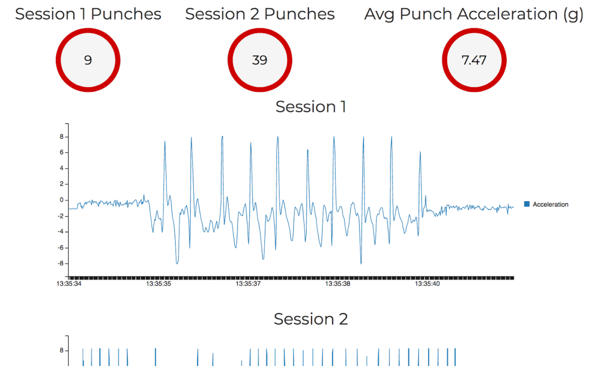
[Figure 25: Overview page]

The next section contains the displays of two circular graphs, the left is for the number of punches thrown and the right is for the average punch acceleration of the session. Just below that is the line graphs of the files uploaded [Figure 26].



[Figure 26: Graphs]

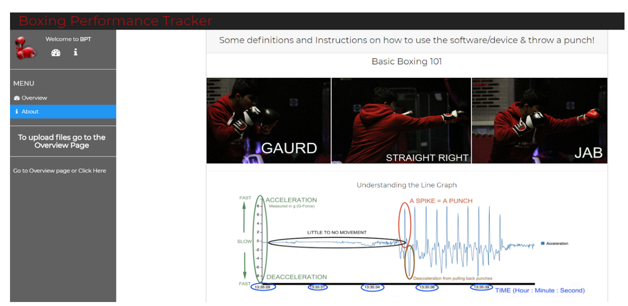
The final section of the overview page is the comparison section which includes the number of punches and the individual graphs of both sessions uploaded, to allow an easy comparison of each [Figure 27].



[Figure 27: Comparing sessions]

7.2 About Page

The other page on the system is the about page [Figure 28]. The use of the about page is to assist anyone that may not understand any feature or procedure that may be difficult to understand. This includes basic boxing 101 which is the foundations of boxing, Understanding the line graph, Average punch acceleration, instructions to use the GENEActiv software/device and save the recorded files as CSV to be uploaded onto the website, how to save the CSV files with a date, x and y column if it isn't already formatted like that, understanding G-force and acceleration, and finally at the bottom a two links to YouTube tutorials, one being a recommended boxing tutorial and the other being a GENEActiv tutorial.



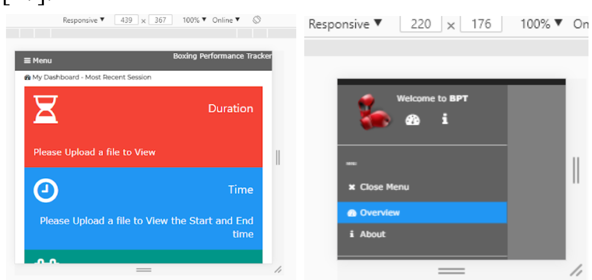
[Figure 28: About Page]

7.3 No Data Stored

One significant aim was to not have data be stored permanently, as I want users to simply upload data they have recorded and view the results, without the need for an account or membership. This allows users the freedom of using the app without worrying about a breach of data protection, access to sensitive data or their data being leaked/hacked. As the system does not make use of a database, there is no way to permanently store data uploaded to the website. This means that users that miss a day of training won't return to the system seeing negative results effected. The system only makes use of days where user has recorded and uploaded training sessions.

7.4 Mobile Friendly

To follow the aim of making the system accessible on any device the system followed responsive web design to be mobile friendly [Figure 29]. This allows users to make use of the system even on devices as small as their Smartwatch (Smartwatch resolutions being 220 x 176) [27].



[Figure 29: Smartwatch]

8 Appraisal

Overall the developer is satisfied with the project and considers it a success, due to his main aims; Viewing number of punches thrown, the average speed of the punches and making it accessible on many devices were achieved. At the very beginning of the project the developer's first aim was for a system that simply alerts users on how many punches were thrown, but from research, testing and development, a system that could do that, and more were brought to fruition.

8.1 Issues

Although some of the features originally intended to be implemented were not accomplished, like being able to alert users when their guard was down and having the statistics for right hand and left punching. Others were attempted, developed and were fully working at some point during development, but in the last stretch of development found bugs that prevented it from being fully functional due to lack time to fix the bugs such as the comparing session section, proof in [Appendix D - Logbook]. If implementation of the system is continued these issues could be ironed out and the website can be enhanced.

Another issue was being able to adopt a device and work with it from the start to the end of the project, as shown when the Bluetooth accelerometer with Cordova was used for development but was found to be faulty due to the Bluetooth transmitter not being fully functional and having issues with emulators with Cordova and android studio. Later on, when the GENEActiv was discovered, late into the project, the time available to spend on implementation and testing was drastically decreased. If this project was to be repeated the developer would look for an off-the-shelf robust wireless measurement device with direct access to the raw data or ask the university if they could provide accelerometers that can record raw data straight away instead of using an untested Bluetooth accelerometer module and start on development/testing earlier.

8.2 Changes

The developer would make subtle changes to devices and testing methods. One aim early on, was to allow the for punch statistics to be viewed in real time, however, the GENEActiv Original did not have the capabilities to wirelessly transfer data, unlike the GENEActiv Wireless which would have, but one was not able to be acquired. As the project was sports-focused the GENEActiv Action would have been preferred as it records acceleration of up to 16g. This would allow for more accurate readings of punches and acceleration overall, but again, the device was not able to be acquired

Many of the features intended to be developed were not possible due to the lack of a gyroscope in the GENEActiv Original. The gyroscope would provide tracking of movement, and from that, the type of punch could be distinguished which would allow for more analysis for example, how fast the user's jabs were.

8.3 What Was Gained

Through these challenges and tribulations, the developer used knowledge gained from previous modules in the four years studying Applied Computing BSc (Hons) at the University of Dundee, but also gained many skills including but not limited to programming in JavaScript to make Grunt and Browserify accessible, using NPM libraries and plugins, starting development with Cordova for native mobile application, on top of simple day to day enhancements such as time-management and prioritising tasks.

9 Summary and Conclusions

9.1 Future Work

In the event that the continuation of this system proceeds, many features and enhancements would be implemented. These would consist of:

- Being able to asses and convey to the user what type of punch is being thrown, this would be achievable through development with an alternative device that includes a gyroscope into its product.

- Implementing a method of alerting users in real time that their guard is not up, to get them into the practice of always having their guard up, or similarly record their retraction, which would show how quickly they bring their hands back to the guard after a punch is thrown.

- Implement a loading bar for when larger files are being uploaded, to view the progress of how much has been uploaded and/or if the system has crashed.

- Implement a small interactive tutorial on the website so users are explicitly shown how to use the website, software as well as learn how to box.

- Enable calorie tracking and calories burned, to visualise and motivate users showing how much they have burned in the training session or compare to previous training sessions.

- Implement a setting option to take into account the fighting style of a user, ie Southpaw, Shoulder Roll etc. This allows for features such as guard drop to not be mistaken for negative practices.

- Integration with devices, such as Misfit shine which doesn't have any options to output raw data for people to analyse, save or use.

9.2 Summary

To give a readable condensation of the project, a user-friendly system that allows all users, including the targeted user group, amateur boxers, to upload recorded raw accelerometer data to a system which allows users to visualize and analyse their boxing performance was brought to fruition. It was achieved through gathering user requirements from currently available products reviews and performing questionnaires to build a set of aims and objectives to develop.

Throughout development sensors and technologies were replaced in order to use the most relevant and useful products/technologies for the system. Through further user testing of the developed system, NASA TLX assessment was obtained along with enhancements and features to be added to future development. From research, testing and development, the use of software and technologies was learned, such as c3.js, PapaParse, grunt, Cordova and browserify.

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Appendices

Appendix A - User Manual

Appendix B - Gantt Chart

Appendix C - Product Backlog and User Stories

Appendix D - Logbook

Appendix E - Available Products

Appendix F - Prototypes

Appendix G - Sensors Tested

- Bluetooth Accelerometer
- Misfit Shine
- Fitbit Charge HR
- GENEActiv Original

Appendix H - User Testing

- User Testing Sheets/Questions
- User Testing Results

Appendix I - Ethical Approval

Appendix J - Poster and Demonstration

Appendix K - Minute Meetings

- **Supervisor**
- **Markus**

Appendix L - Source Code and GitHub Link