An IoT System for Improving at Archery

Group 13

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Introduction

ARCHiE is the everyday archer's toolkit to gain access to professional standard coaching, right at their fingertips. ARCHiE aims to use modern technology, already available to the user, alongside the Internet of Things (IoT) to track the users training and provide analysis to help improve their technique and accuracy. In this report we aim to outline the design process and decisions that led us to this proposed solution.

This report describes the whole project from scratch and has been completely modified since the Initial Prototype submission.

Methodologies

Double Diamond

The *Double Diamond* design methodology is an illustration that captures the common phases of the design process that happens in a project. Two of these phases are attributed to *divergent* thinking (Discover and Develop) and the other two to *convergent* thinking (Define and Deliver). These are arranged such that a problem is discovered and defined then a solution is developed and delivered. Many problems and solutions are explored throughout this process. This methodology was developed by the UK Design Council in 2015. Figure 1 is an image that shows the transitions between phases in the methodology.

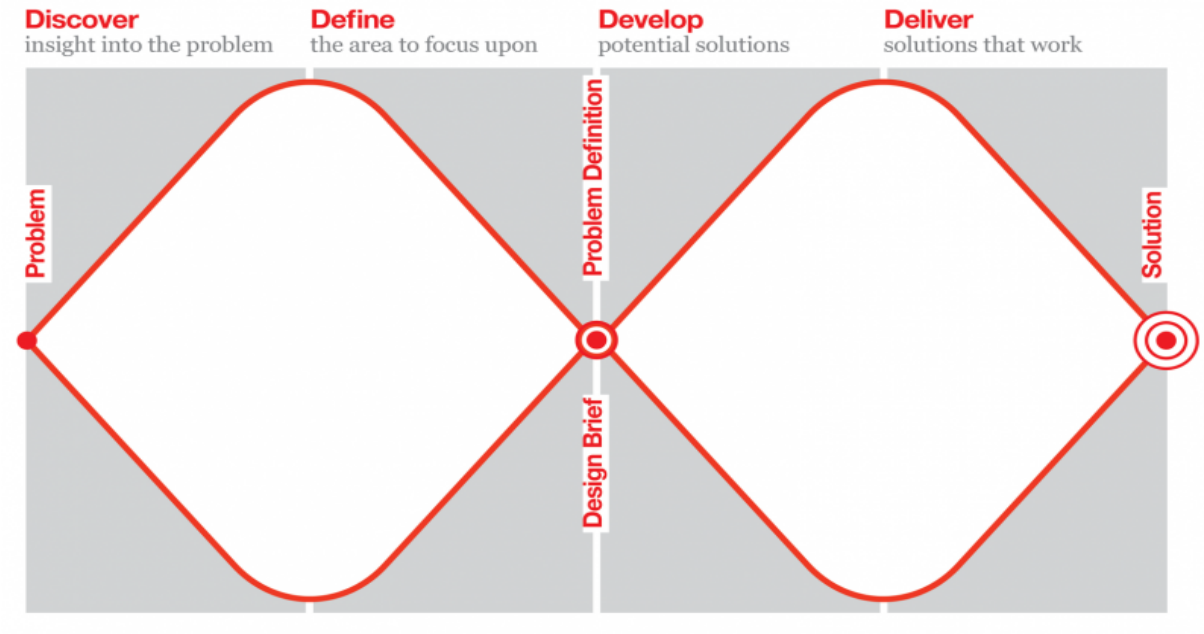


Figure 1 - Double Diamond Methodology

We used this methodology because it encouraged us to be conscious of the approach we took to not only creating the solution but also defining the problem. Exploring the problem space effectively and identifying a clear problem to solve made it easier to verify that the delivered solution is appropriate. This is valuable in a project which is time constrained so that time is not spent on solutions that do not solve the problem.

Initial Problem

The problem we aimed to address at the start of the process was to use the *Internet of Things* to solve a real-world issue and design a tool that would be beneficial to a group of users. In our first meetings we planned what we will do in each stage of the process and how it will inform the following stages.

Discover

We anticipated that the *discover* phase will generate a selection of different problem ideas that can be pursued. This was mainly done through brainstorming and researching what types of problem we found interesting to take on and their feasibility (not simple but still achievable). It was important for us to take on an idea that we found interesting because it would have been difficult to have the motivation to work on it otherwise. The result of this stage is a general problem area that we wanted to focus on and some in-team suggestions to solve them.

Define

This fed into the *define* phase where we had a general problem area and developed it further. In this phase we undertook most of the research into the problem area in order to ascertain an appropriate target audience and set of requirements. This was followed up with a thorough ethnography so that we could gain a better understanding of the problem domain and also to get feedback from users of that target audience and what problems they were facing. This was done in the form of questionnaires, interviews and field studies. Doing this meant that we did not try to solve a problem that did not exist. After iterating on ideas with users, a collection of requirements for the system can be formalised. Personas and storyboards can also be created to facilitate this process and give us an idealisation of what we want to achieve. The result of this stage is a full description of the problem domain, target audience and requirements for the system.

Develop

Once the problem has been formalised, designs for the system can begin to take place which forms the *develop* phase. This is where we will decide how we want to solve each of the requirements and to consider alternative solutions to each requirement. Justifications are necessary for why decisions are taken and what the implications of such decisions are. We acknowledge that we must note what data we want our system to capture and also what data we do not intend for our system to capture. We expect a large portion of our time to be spent in this phase working and reworking designs with our users because it is essential that we create something that is useful for them. A simple proof of concept should be developed to illustrate any designs that are produced. The result of this stage is a set of designs and a proof of concept that solve the initial problem and satisfy the list of requirements and personas.

Deliver

The *deliver* phase focuses on release and will be evaluating the success of the project and where the project can be taken forward in the future. The result of this stage is this report, a

video and a poster of the product alongside evaluations of the success and improvements for the future (present in the report).

Team Organisation

We agreed early on to use Facebook Messenger as a mean for communication. We already knew each other well prior to starting the project so setting up a dedicated group in Messenger was easy. It was something we had all used before and would all be active on throughout the project (unlike Discord or Slack which different members use with differing frequency). The drawback of this is that Messenger is a platform that is used primarily for non-work activities so does not help to split up the work-life balance.

Google Drive is a valuable resource that we use heavily to share our work and designs. This means that we are able to share work whenever we want other people to review it (with a prompt on the Messenger group to ask for this feedback). Everyone can see all of the documents in our shared directory in real time and documents can be edited collaboratively.

Free versions of software such as Balsamiq Cloud, Lucidchart, Storyboard That[1] and Free Logo Design were used to create many of the diagrams we needed for our project. Balsamiq allowed us to create mockups of the mobile application and Lucidchart for UML diagrams. Storyboard That is a platform for creating storyboards and Free Logo Design gave us a way to create brand logos.

As a team we decided to meet at least twice a week, with some weeks having more if we felt it were necessary. This was especially the case in the first few weeks and the final few weeks where we were consolidating our project and producing the deliverables. The usefulness of the Messenger group and Google Drive collaboration was a major factor in not needing to meet more frequently because we could discuss any issues there. Face-to-face meetings allow a better flow of conversation so these were primarily used for generating ideas and agreeing plans for the project, while Messenger were used to give status updates on different areas of the project.

Risk Analysis

Undertaking a project of this size has risks associated with it. Risks are situations that could jeopardise the success of the project. We agreed processes to mitigate as many risks as possible. Below is a table showing the major risks we considered, their risk factor (as a measure of likelihood and severity) and how they were mitigated. Likelihood and severity are on a scale of 1-4 where 1 is low and 4 is very high. Risk factor is simply the product of likelihood and severity. Any risk factor above 7 is a cause for concern.

Risk	Likelihood (1-4)	Severity (1-4)	Risk Factor (L*S)	Mitigations
Prolonged illness within the	2	2	4	It is likely that any single individual will be ill (but probably not for long).

[1] "Storyboard That." http://www.storyboardthat.com/. Accessed 03 Feb. 2018.

team				In this case the workload can be shuffled to accommodate the illness. It is extremely unlikely that all members will be ill at the same time for a significant period. In this case advice from the project supervisor would be sought.
Work rate/ motivation decreasing	3	3	9	This is a deceptively serious risk especially with larger scale projects. Regular meetings and breaking tasks down into achievable chunks will help to maintain motivation.
Loss of work	2	3	6	The severity can vary depending on what work is lost. This can mostly be alleviated by maintaining backups. Using version control (Github) and shared real-time resources (Google Drive) should make it more difficult to lose work as it is unlikely to be prone to machine failure. Of course, accidental deletion of files is still possible so local backups should be taken too.
Duplication of work	3	2	6	This can be prevented by maintaining regular communication within the team. The use of a Messenger chat for the team allows real-time updating of who is working on what so any overlap in work can be identified easier.
Spending excessive time on ineffectual solutions	3	3	9	This is hard to alleviate if the solution is not obviously inappropriate. To reduce this risk it is important to maintain communications with the archery society so we can iterate our designs and make sure they are relevant.
Not being innovative	2	4	8	It would be bad to release a product that offers nothing new. Staying up-to-date with products and technology usage in the problem domain will help to ensure that our solution has not already been done in its entirety.

Discover & Define

Deciding a Project

Brainstorming

After we decided on the methodology to use to organise ourselves for this project, we implemented the first phase within the the double diamond plan; Discover.

This phase involved us exploring various different ideas for their scope and initial feasibility as a project that we could delve into for the whole semester. We decided that the first logical step as part of this phase would be to have a brainstorming session where we could have a look at different ideas which interested each of us and see which ones will be viable as a project. This is the summary of the brainstorming session:

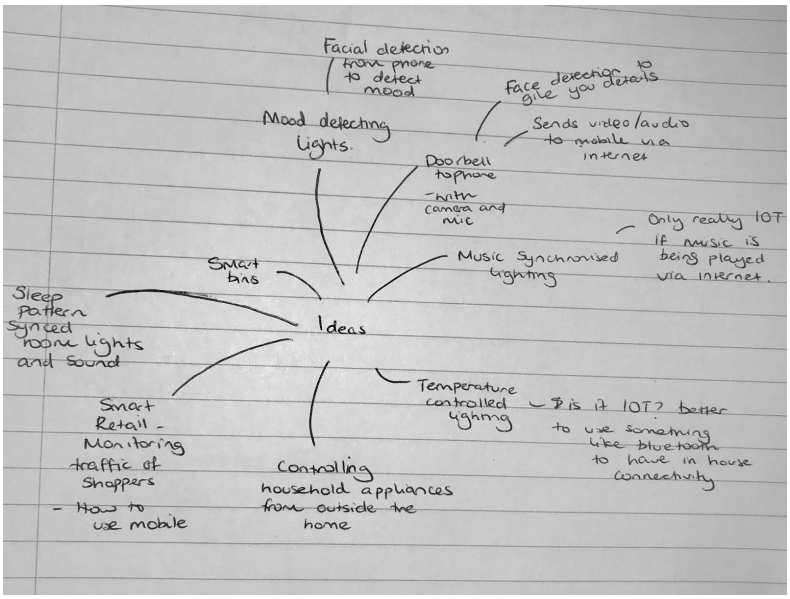


Figure 2 - Ideas Mind Map

From these initial ideas we decided that we need to analyse them more formally and look at four different aspects: which problem each of them is trying to solve, the proposed solutions, the pros and the cons of each solution. So we each decided to take one of the ideas discussed and research it further to explore the problem space more before deciding on which one to go forward with further. We also had to ensure that they met the criteria provided as part of the project:

- Commercially viable
- Addresses a real world issue
- A mobile phone must be present in the solution
- Cannot be linking up devices alone, must contain some AI/Machine Learning/Algorithmic processing

So with all this in mind, we produced a more formal analysis of each idea.

Initial Ideas

Sleeping Pattern Controlled Alarm Lighting (SPCAL)

Problem

As university students, waking up in the morning for an early 9am can be a difficult thing to do. Normal alarms do not seem to be enough anymore as we all just seem to sleep through them or get into a routine of being able to snooze them.

Solution

Recently, technology which is able to monitor sleep patterns has been arising and one of the main uses of this data is to be able to set alarms to wake you up according to your sleep cycle, i.e. when you are in your lightest sleep closest to your preferred wake up time. We take this idea a step further where both the lighting and sound could be controlled in a room so that it gradually gets brighter and louder as you slowly come out of deep sleep to wake you up feeling refreshed.

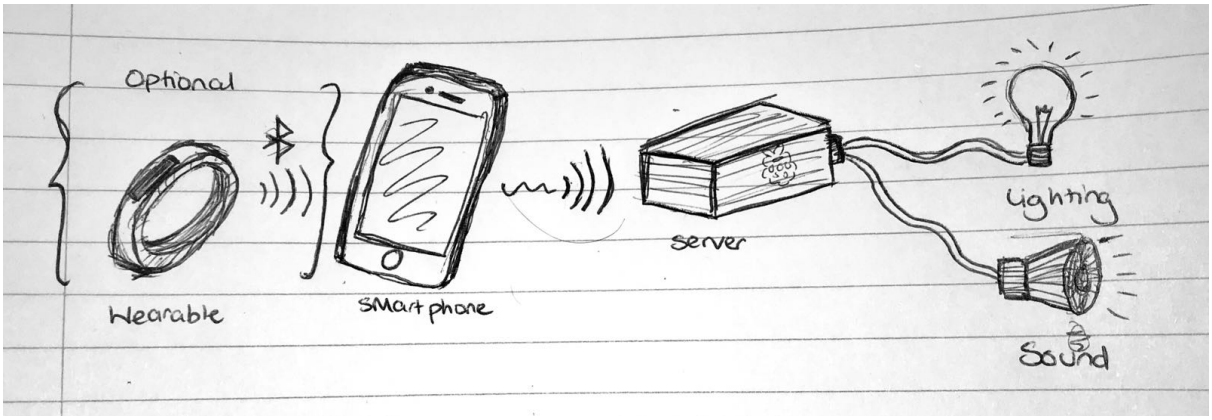


Figure 3 - SPCAL Structure Diagram

The basic idea behind this would be that the user would use a wearable device connected to a mobile phone (or the mobile phone only) to collect information about the users sleep and try to identify the pattern and differentiate the sleep cycle. Once it has done this it will use an algorithm to determine the closest time to your preferred wake up time where your sleep is at its lightest part in the cycle. It will then transmit this information to a server that will be connected to the the lights and speakers in the room to slowly increase the lighting and alarm sound to wake you up in a gentle and refreshing way.

Pros:

- This has commercial value as it solves an everyday problem using modern day technology and ideas with the use of IoT
- The algorithmic processing required as part of the solution is not very complex so should be feasible to implement
- APIs should already exist to be able to detect sleeping pattern using wearables or phones so our own implementation in this part is not necessary
- Could extend further to include machine learning about users' sleeping routines and start tailoring experiences according to the user over time

Cons:

- May be too similar to existing idea, see Philips Hue[2] light, which is compatible with certain applications monitoring sleeping patterns and then controlling the light. However we plan to make it as one integrated system including sound as well rather than offer just the light
- May be too simple as there is not much processing required, just using APIs and sending data over to server to change lighting and sound.

[2] "Hue personal wireless lighting | Philips Lighting." https://www.philips.co.uk/c-m-li/hue. Accessed 15 Jan. 2018.

Trolley Tracker

Problem

Technology has had a profound impact on the way people shop in recent years and retailers are always trying to keep up with their increasingly digitised customer base. People are able to do their grocery shopping from their homes and can check stock/prices online for many different retailers. Therefore, it is important for retailers that when customers do visit their brick-and-mortar stores, the shop is organised effectively so the retailers get as much return from customer visits as they can.

Solution

A tracker could be fitted to trolleys and baskets that would allow the retailers to monitor the route that was taken through the store. That route could then be sent to a connected smartphone (potentially owned by a site manager) where other routes are stored. From this, hotspots in the store can be calculated and displayed on the smartphone to the manager so that they can see where customers go the most. This means that any special promotions or higher value products could go in these areas where they are most likely to be viewed and bought.

This could be done by fitting the trolley or basket with a Raspberry Pi which has a GPS sensor attached to it which allows the Raspberry Pi to collect coordinates of its location. These coordinates would then periodically be sent to a smartphone. The application on the smartphone would then algorithmically work out hotspots to display on screen in an understandable way for the manager. The Raspberry Pi would need to reset somehow when the route has finished (i.e. the customer has paid).

Pros:

- The retailer has data to back up where busy spots in the store are, meaning they do not have to guess as much when it comes to placing promotions.
- Data will be anonymous because it is not tracking customers directly (the only thing being tracked is the path that the basket/trolley takes).
- If baskets/trolleys are stolen, the GPS signalling could allow them to be located.

Cons:

- The data is only useful to that specific store, there is no margin for profit in selling it on.
- Will require equipment to get it set up on all baskets and trolleys that a retailer owns.
- Ensuring connectivity across the store may be difficult in large stores such as supermarkets.

Mood Lighting

Problem

Entertainment has been a growing aspect in our daily lifestyle, however there has not been much IoT entertainment. As mobile phones and the Internet have become more widely used, it would make sense to take this as an advantage and create something interactive and entertaining.

Solution

Cameras could be fitted around the room (potentially in the living room) to detect the faces and capture images to send to a server running on a Raspberry Pi to analyse the images. From the analysis, the server will be able to tell the overall mood of the room and adjust the lighting accordingly. With mobile phones, you are able to tell what mood the lighting represents by logging on to the server itself. This data can be seen from anywhere around the world over the Internet as long as the phone is authorized to do so. If the mood lighting is not ideal at certain times, for example when going to sleep or watching a movie, this can also be turned off on the mobile phones. The system could potentially learn this behaviour or be scheduled so it automatically turns this feature off at given times.

Pros:

- Livens the environment in a room with dynamic lighting
- Helps people to be aware of the mood in the room so they do not say or do the wrong thing.

Cons:

- Easy to forget the feature is turned on, therefore privacy is exposed
- Facial recognition is not completely accurate and reliable
- If server analyses the facial images incorrectly, people would get the wrong idea from the lighting

Shot Tracker

Problem
Accurately and conveniently track where your shots land, and give feedback on the archer's form and technique.

Solution
Have a system that accurately and automatically records shots as they land. The system might then be able to figure out suggestions on technique based on trajectories of arrows, or where they land. Alternatively or additionally, have the system monitor the bow or shooter, allowing more information to be collected.

Initially thinking of either a camera mounted on the floor in front of the boss, or a camera that goes on the boss itself. Would need to consider how the camera detects the target face, and how it determines where the arrow hits the face. Would also need to do research into if it is possible to judge the archer's technique based on where the shots fall. Also need to see if the system only recognises where the shot lands, or if it can also recognise trajectory.

The camera would transmit the data to the phone, so the user can see immediate statistics and use it as a basic shot tracker. The functionality of analysing shots is then a separate feature, where the data is sent to a server to do any machine learning and pass the data back to the phone.

Sensors on the shooter would begin with motion detection on the bow hand, to see how steady their aim is, and if the release is as good as it should be.

Pros:
- Able to pick how we start this system
- Able to decide which direction to take this
- Have a specific and clear purpose

Cons:
- Probably involves high amounts of computation vision (if we use a camera)
- Niche market (although that is not always a con)
- Testing is more difficult than other systems, but testing can be regular

Controlling household appliances remotely

Problem

Sometimes when we go outside our house we are not sure when we would be back, so even if we can set a timer for when an appliance should turn itself on, it is not as efficient as us being able to turn it on remotely from anywhere. There are a lot of such systems on the market, systems that allow you to connect smart home appliances to your mobile phones through various applications, therefore it is hard to come up with innovative ideas in this field of IoT. We came across the issue of not being able to answer the door when you are away from home or when you do not hear the doorbell.

Solution

Our system would involve having a camera, a microphone and a small speaker installed on the front door or near it. The doorbell would be connected to the phone through the internet and whenever it is pressed, the phone would ring. The user would be able to see and talk to whoever is at the door through the camera, microphone and speaker that would also be connected to it through the internet. To make this system more complex we could add face detection and recognition that would take a picture of the person at the door and then give more information on them to the user, such as hair colour, eye colour, gender and whether they can be recognised from a set of faces stored by the user in the system.

Pros:

- Can check whoever is at the door from anywhere, inside or outside the house
- Would cost less than an intercom system
- Easy to use by anyone since it would be very similar to having a video call
- Makes it safer to talk to unknown people since you do not have to open the door to communicate with them

Cons:

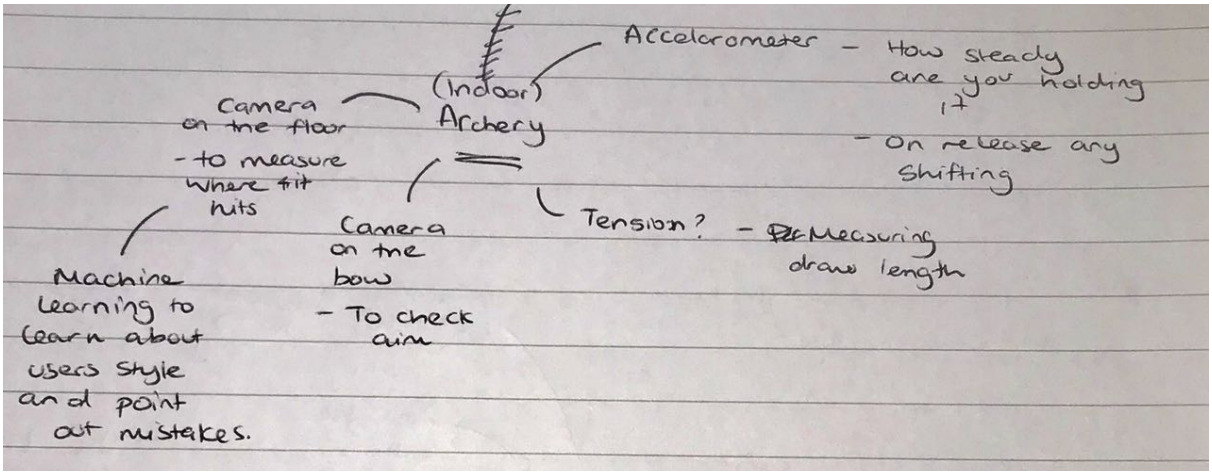
- Face detection and recognition can be inaccurate
- The system does not allow the user to open the door remotely to people they trust
- Very similar to already existing solutions

Evaluation

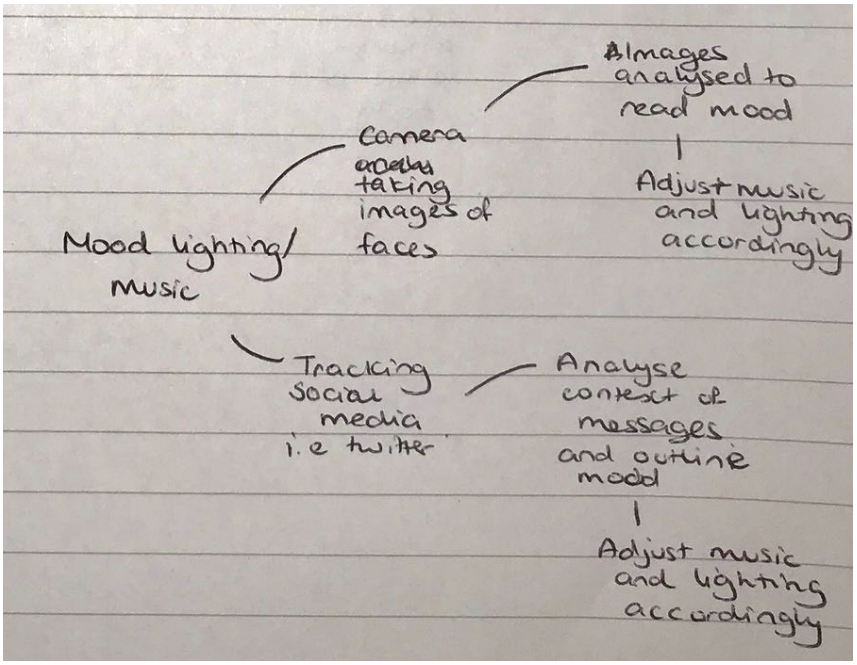
After evaluating all of these we agreed as a group to explore the idea behind Sleeping Pattern controlled lighting. We believed at the time that this was the most innovative idea out of the ones that we came up with while still being the most feasible for us to produce as well as being easily commercially viable.

However after later discussion and exploration into the project, we realised that we needed to develop the ideas further as they were too confined and we did not explore the problem space enough. We realised that we could collect a lot more data from more than just one sensor and collate the information to create a more complex and all round solution which provides more functionality.

So we decided to revisit the ideas in a brainstorming session to see how we could develop it further and see what ideas we had for expanding each idea. From that we produced the



following brainstorms:



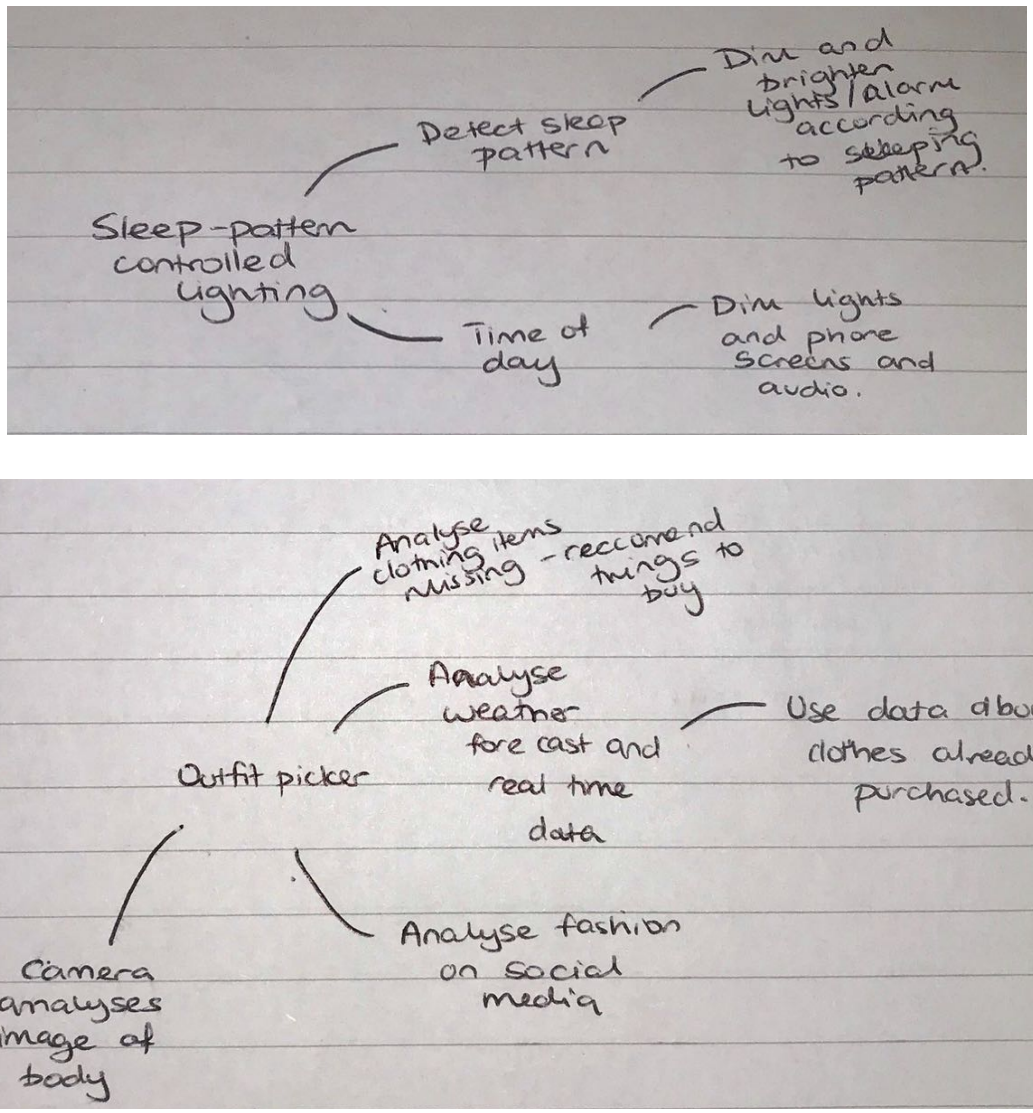


Figure 4 - Mind Map of Ideas' Features

We then decided that we wanted the explore the Archery idea further and see what problems we could solve in this field using IoT, as it has more scalability and development.

Research

After deciding that we want to focus our project around archery, we wanted to do research into the domain. Research was essential because only one member of our group has experience with the sport. We investigated as a group so that we all gained a sufficient level of familiarity and understood what problems can be solved. This was done through the use of ethnographic study processes such as conducting market research, interviews, developing a questionnaire and field studies. These helped refine the problem we were tackling and ensured that we were not solving a problem that did not exist. Research into processes and technologies relating to the Internet of Things was also vital due to none of us having worked with this paradigm before.

This research allowed us to generate personas and storyboards for our system which we used to validate our designs prior to getting feedback from the study group. The storyboards give a pictorial view of the flow of the system and will aid in the explanation of how the system would be used.

Market Research

We have explored the market for archery related applications to gather ideas on what they try to do for their users. The Internet of Things paradigm has so far had the most success with wearable technology in sport[3] but is still limited to the highest levels of competition (with all teams in the rugby league Aviva Premiership embracing the technology). Despite this, there is a lack of this type of technology in archery. One example is a smart arrow developed by Full Flight Technology that has an embedded accelerometer that measures arrow speed, flight dynamics and bow performance[4]. The small size and high resistance to shock of this particular accelerometer allows it to work in the arrow, which is potentially interesting to us. The barring factors for implementing something like this ourselves would be the cost to produce the product and whether users would want to have to replace their arrows which they may have pre-selected in the past for themselves.

The most frequent technology that people have access to and regularly use is mobile phone applications. We found some high quality examples in interviews that members of the archery society at the University of Birmingham use. Some of these examples are Artemis and MyTargets.

MyTargets is a free mobile application that archers can use to track their performance over time. The user starts on a menu interface, which is either on Training, Bow or Arrow. On these menus, the user simply inputs or changes entries of the selected type. To begin shooting, the user navigates to the training tab and selects the session they wish to add to. They then select which equipment they are using from the entries and inputs the details of the session. Once in a session, the user can navigate between rounds and ends (an end is a sequence of shots), and enters their shots on an on-screen face. After an end, a simple

[3] "The wearable tech giving sports teams winning ways - BBC News." 15 Apr. 2016, http://www.bbc.co.uk/news/business-36036742. Accessed 13 Jan. 2018.
[4] "Smart arrow uses ADI MEMS sensor - Electronics Weekly." 13 Dec. 2011, https://www.electronicsweekly.com/news/products/analog/smart-arrow-uses-adi-mems-sensor-2011-12/. Accessed 17 Jan. 2018.

graphic is shown to highlight details about the shooting on that end. Once the user has completed their shooting, or once some data has been entered, a statistics screen can be viewed. This shows average score from end to end, as well as distribution of scores and dispersion of shots.

The application takes a simplistic approach to the interface and design. This is something that we decided we wanted to replicate. We thought the bar at the bottom for navigating between menus was good. The face interface is simple and effective, and if we decided to use manual input for shot tracking, it will be done similar to this. The colours blend together well, and allow for quick identification and overview.

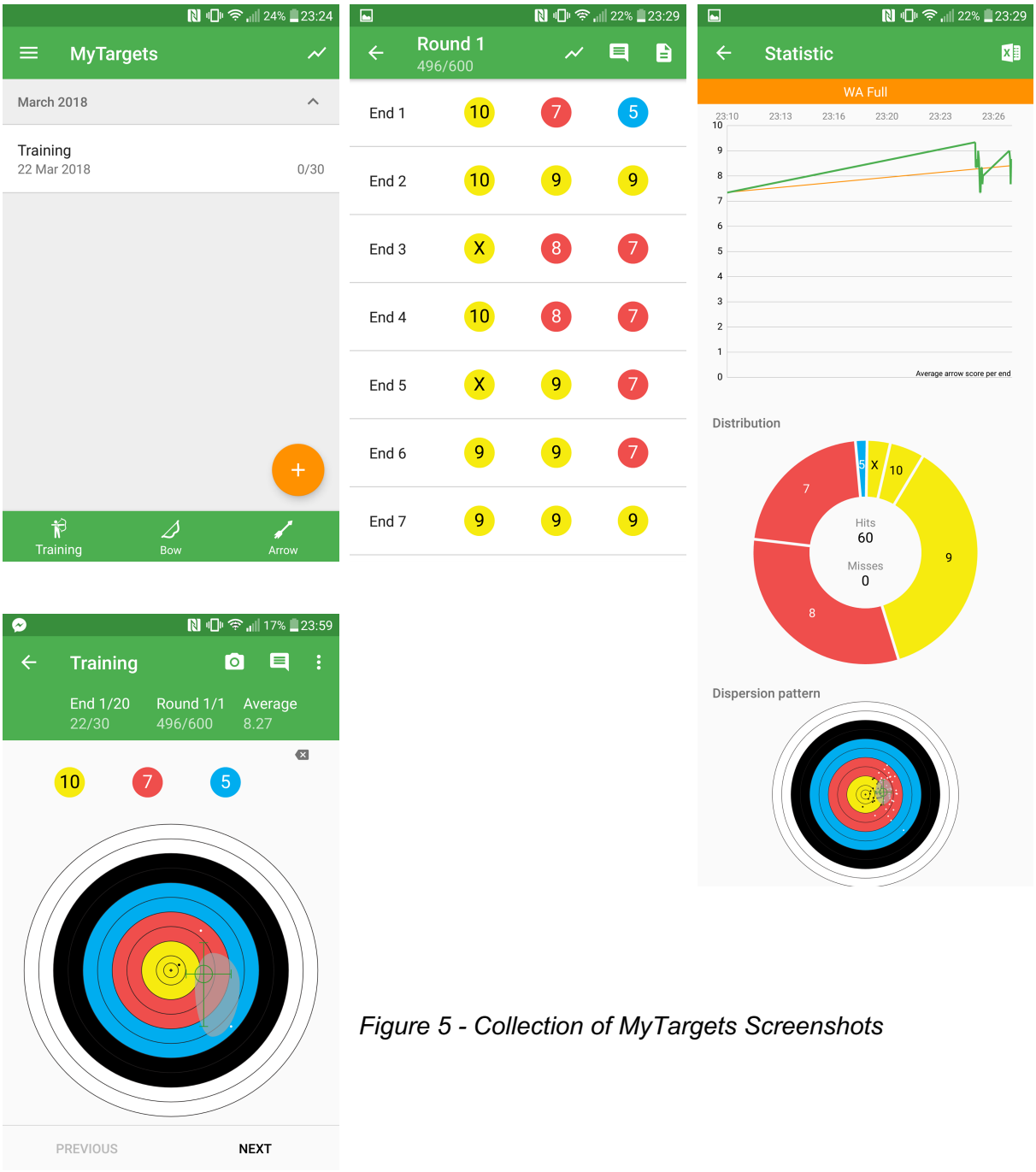


Figure 5 - Collection of MyTargets Screenshots

Artemis is a similar application developed by a world-class

archer which offers all of the above for free, or if the user is willing to buy the full version, advanced analysis on performance. The user is greeted by a menu system of 4 tabs. Artemis offers the ability to go into a lot more detail than MyTargets. Whether this is a benefit is debatable. All data necessary to shoot can be entered into MyTargets, and it can be argued that a lot of Artemis is taken up by clutter of extreme data fields which the average archer will never use. However, Artemis is not designed for the average archer, and all of these extra details go towards fine-tuning a service Artemis offers that MyTargets does not; suggestions for sight movement and arrow analysis. Artemis attempts to identify if an arrow is bent or dodgy if it is consistently inconsistent or different to other arrows. If the user is shooting off target as a whole, Artemis suggests how to move their sights to adjust or compensate.

These suggestions are similar to what we want to build our project around, and we can offer suggestions in a similar way. Overall, we agreed that MyTargets' interface was cleaner and easier to use, but we should offer a similar depth in detail that Artemis provides.

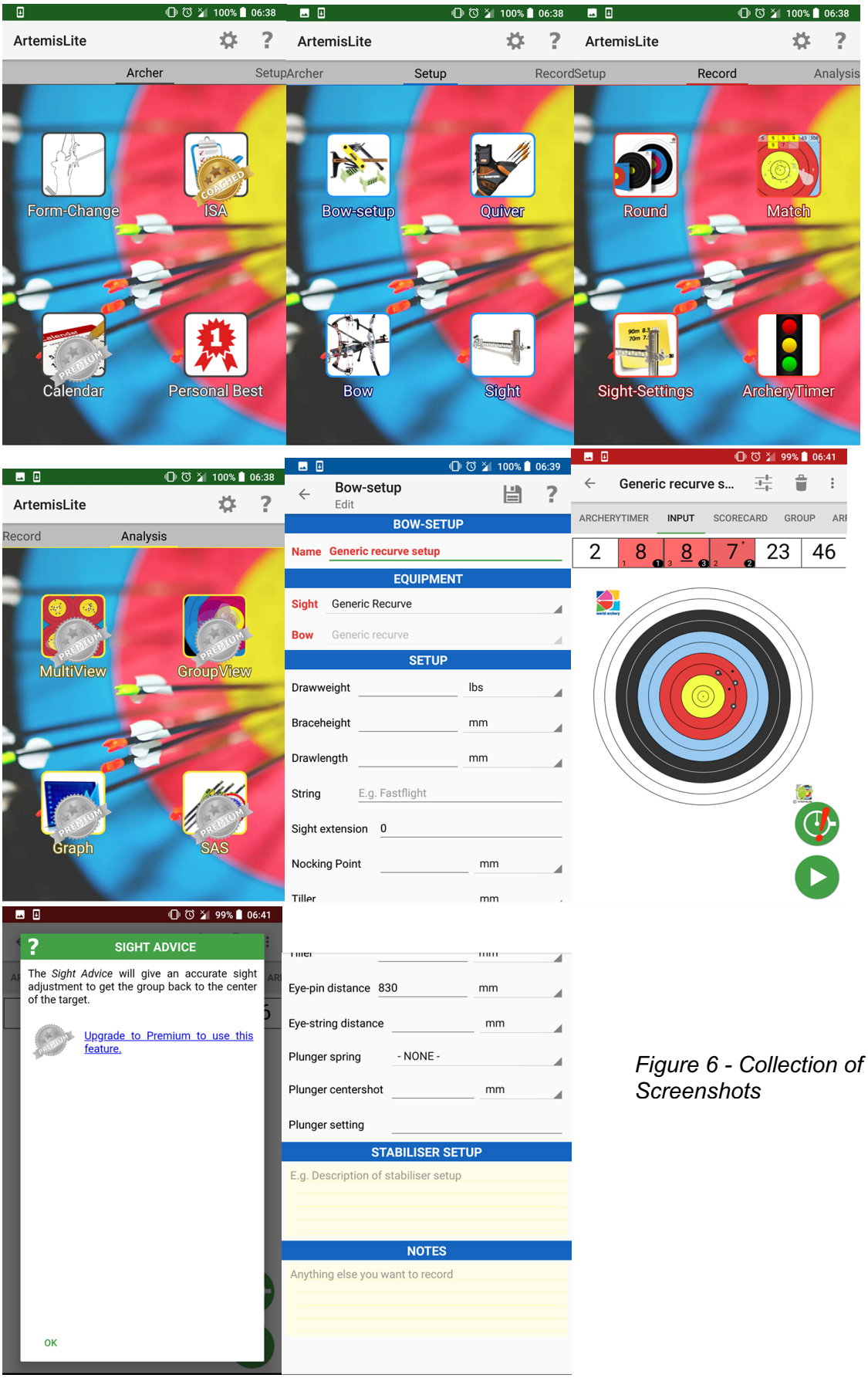


Figure 6 - Collection of Artemis Screenshots

In the final week of this project, Lancaster Archery released a video[5] detailing a similar product to ours, the Sweet Spot. The Sweet Spot has quite a similar design to ARCHiE, but addresses a different problem while receiving a lot more funding. Their product involves a strain gauge that measures incredibly small deflections in the riser to identify draw length. Users can set the draw length that they wish to use, and tiny LED lights that are placed in the sights inform the user when they are at optimal draw length. Two different lights are used, a green light that illuminates once they draw back far enough, and a red light that illuminates alongside the green when they draw too far. While this may initially be thought of as obstructive, users say the lights do not get in the way of the sights, and the product was incredibly useful for ensuring that they always drew to the same length. The sensor is mounted in a similar style and a similar place to what we had decided to do with our product, confirming that our design for mounting our sensor to the riser of the bow is feasible and practical. Although it is worth mentioning that their sensor needs to be on the riser due to the measurements it takes.

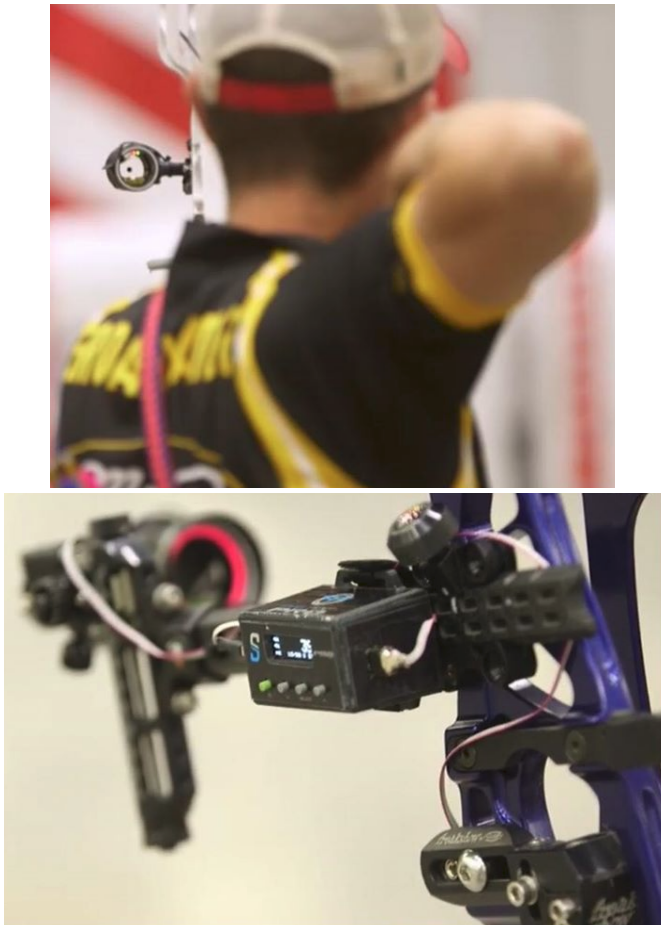


Figure 7 - Sweet Spot attached to bow

Their product also includes a mobile application that displays data gathered, which the users typically look at after shooting their end, or a partner can observe this data live. The mobile application appears to contain a shot counter so the user is aware of how many times they

[5] "Here's a real game changer in the... - Lancaster Archery ... - Facebook." https://www.facebook.com/lancasterarchery/videos/10156164666334254/. Accessed 18 Mar. 2018.

have shot in a session, and stores data over many shots so the user can see consistency. It records the sensor's measurements over time, so the archer can see how they drew over the period of an individual shot.

Figure 8 - Sweet Spot Mobile Phone Application

It is worth noting that the product is not allowed to be used at the highest competitions, but a lot of competitions have cleared the product for use. In the competitions that do not allow use during shooting, archers are allowed to simply unplug the USB power supply, and that is sufficient. They do not even need to dismount the sensor if they do not wish to, just as long as the product is not used in any way.

This product effectively looks at the same problem that we considered solving with a strain gauge; measuring draw length so the user can be consistent with their technique. After a lot of research we considered using a strain gauge on the bow, but we could not find a feasible way to make this work within our time constraints. Their strain gauge is also of a better quality then we would be able to purchase within our budget. Their product is being sold commercially for £300 as just the core product[6], or there is an optional add-on[7] that brings the cost to £429. The add on includes wifi connection and a shot timer that flashes when the user has been holding too long.

[6] "Pressure Perfect Products SweetSpot Go/No-Go - Lancaster Archery ...." http://www.lancasterarchery.com/pressure-perfect-products-sweetspot-go-no-go.html. Accessed 20 Mar. 2018.
[7] "Pressure Perfect Products SweetSpot Pro - Lancaster Archery Supply." http://www.lancasterarchery.com/pressure-perfect-products-sweetspot-pro.html. Accessed 20 Mar. 2018.

IoT Architectures

The Internet of Things is when physical devices from the real world communicate and transmit data to each other over the Internet. The physical devices tend to collect and process data from various sources in real-time, allowing humans to interact with the data.

For prototyping purposes, the main IoT electrical device typically used is the Arduino. It is very flexible, inexpensive, and easy to use for beginners. Arduino is an open-source hardware and software platform, which the user is able to send instructions to the microcontroller on the board. It allows the user to learn new things about electrical circuits, and can be tinkered around whenever and wherever.

In order for the Arduino to have the ability to connect to sensor modules, this requires a breadboard. A breadboard is a small solderless board which is designed for temporary prototyping which is perfect for our prototype. The board contains metal strips, categorised as bus strips and terminal strips, which are used for connecting pins from one component to another. Bus strips are used for powering the electrical components and terminal strips are used for holding the electrical components, where the actual connection takes place.

In most projects, data collected from sensors are stored. The data can be stored on a cloud server or on a server hosted at home. Raspberry Pi provides a great way of hosting a server. Raspberry Pi is a small computer with its own operating system and allows us to setup a server. Its size, portability, and low cost is a significant advantage for small projects such as ours.

Mobile Interaction

We are currently in the Ubiquitous Computing Era, which means that there is a large number of machines per user. The computation is distributed across devices and the cloud, the main reason being that nowadays hardware costs virtually nothing and runs from batteries. The most ubiquitous computing device is the mobile phone. Taking advantage of how accessible and easy to use mobile phones have become, we decided to use it as our main interface between our system and users.

Before starting the design of the mobile application, some research was done on how psychology could help us plan our design better, how to make it easy to use and convenient. Some of the fundamental psychological principles that we kept in mind while designing the mobile application were:

- **People do not want to work or think more than needed. What we learnt:**
    - The application should not contain more information than needed
    - Each menu should be easy to navigate to and from
    - It should be straightforward how to get to each menu
    - It should be obvious what each button does
    - The information should be structured and easy to read
- **Human memory is not reliable. What we learnt:**
    - Store the necessary information if the user desires to do so
    - It should be obvious what each button does so the user does not have to learn and remember

- **People are social:**
    - People enjoy sharing various information through social media
- **Unconscious decisions influence physical actions. What we learnt:**
    - The users can be influenced through words, images, colours and stories.
    - Colours could be used to attract the users to the application
    - Icons can make the application look simplistic but attractive as they take less space than images but are less complex and easy to understand
    - Highlighting the right words can help the user find the information that they need quicker
- **People love information. What we learnt:**
    - The users enjoy getting the information that they want
    - Allowing the users to customise what kind of information they receive from the application will attract them
    - Displaying the information in an organised and logical manner will make the user easier to follow

Questionnaire

A questionnaire was created and developed to help identify the problem and ensure our solution had interest and real application. Care was taken to ensure questions were not leading, and every question had the option for further expansion if the participant wished to answer beyond the supplied answers. The questionnaire was sent to the university's archery society, with their permission.

We decided to use an online survey for numerous reasons. A link can be distributed via social media and is accessible on any device. The archery society has a dedicated Facebook page, allowing quick and direct communication to the participants. The results are gathered online and sorted by question, allowing quick and easy analysis of replies. An online questionnaire also avoids problems involving paper surveys (such as distributing copies and trying to retrieve ones that are filled in).

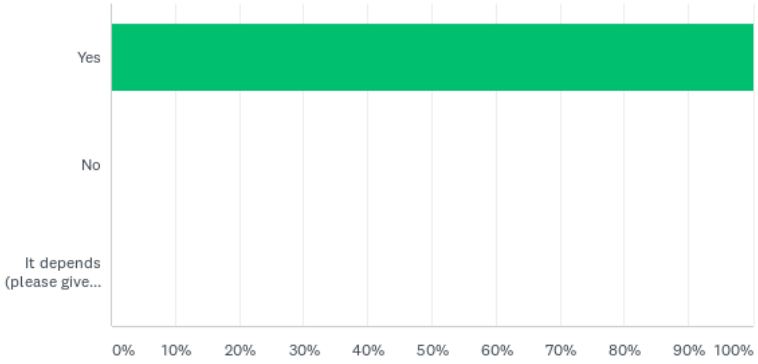
The questionnaire started by asking for opinions on the mobile application side of the solution. We were interested to find out if involving a phone in the solution was practical or desired. The questionnaire revealed about half of the participants have used archery applications before, with most to all participants believing that they would be happy to use their phone as part of the product. We were very happy to see that almost everyone displayed an interest in our ideas, and said they would find it useful for improving at archery. The questionnaire followed up these questions with asking what they liked about applications that have been used, so we knew what features would be desirable or especially good to include. The main feature that participants reported they look for is shot/score tracking over a period of time to calculate averages, see improvement and variance, and observe their own trends in shooting.

Q1

Customize Export

Would you be interested in using your phone to assist in getting better at archery?

Answered: 15 Skipped: 0



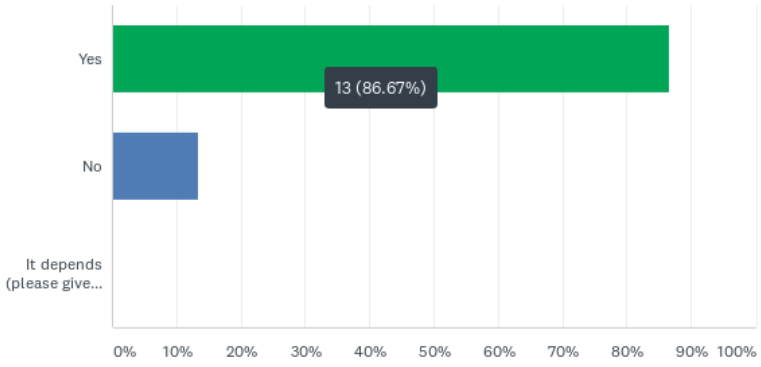
ANSWER CHOICES		RESPONSES	
Yes		100.00%	15
No		0.00%	0
It depends (please give your thoughts)	Responses	0.00%	0
TOTAL			15

Q2

Customize Export

Have you used archery related apps before?

Answered: 15 Skipped: 0



ANSWER CHOICES		RESPONSES	
Yes		86.67%	13
No		13.33%	2
It depends (please give your thoughts)	Responses	0.00%	0

RESPONSES (0) TEXT ANALYSIS MY CATEGORIES

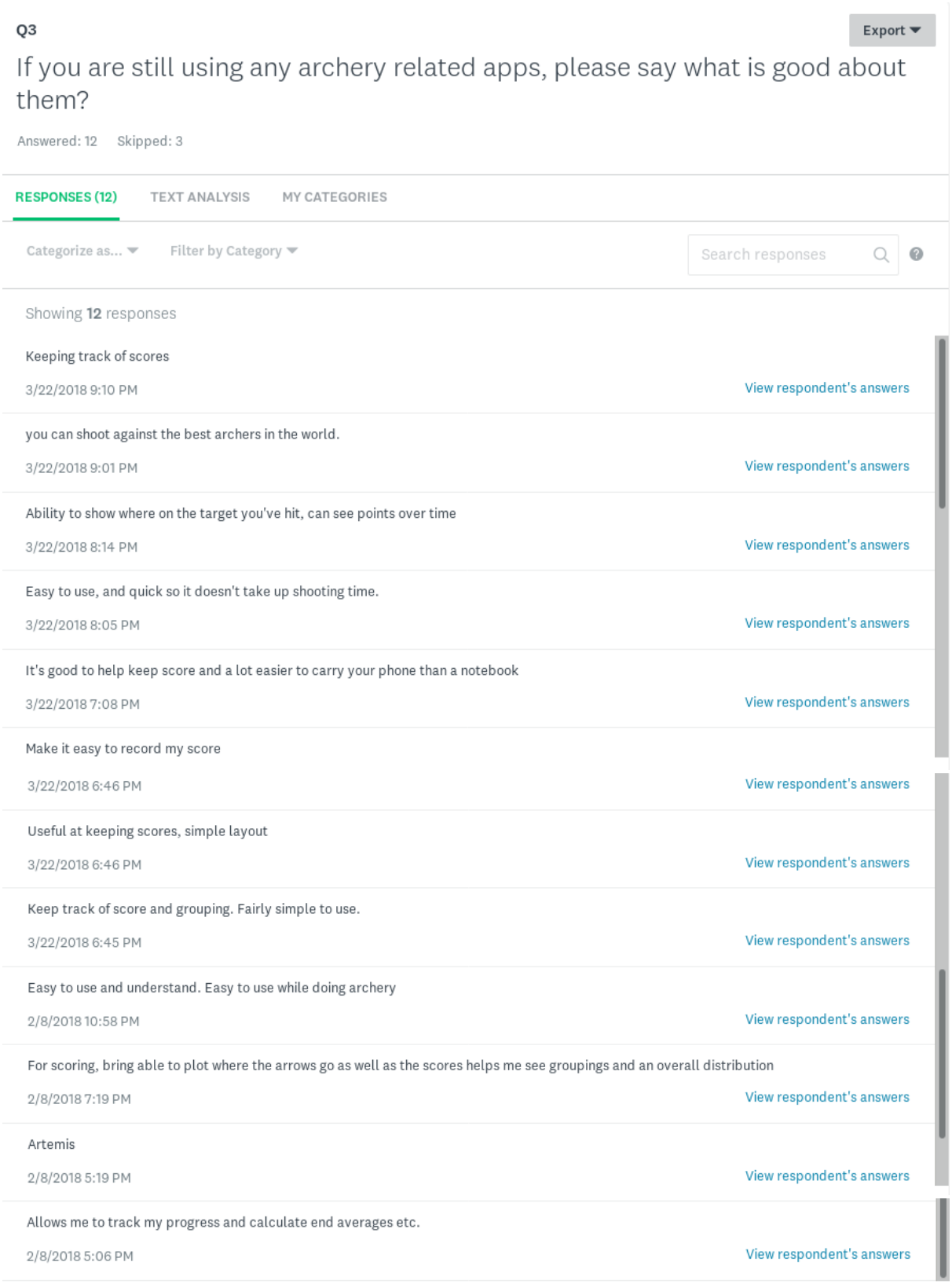
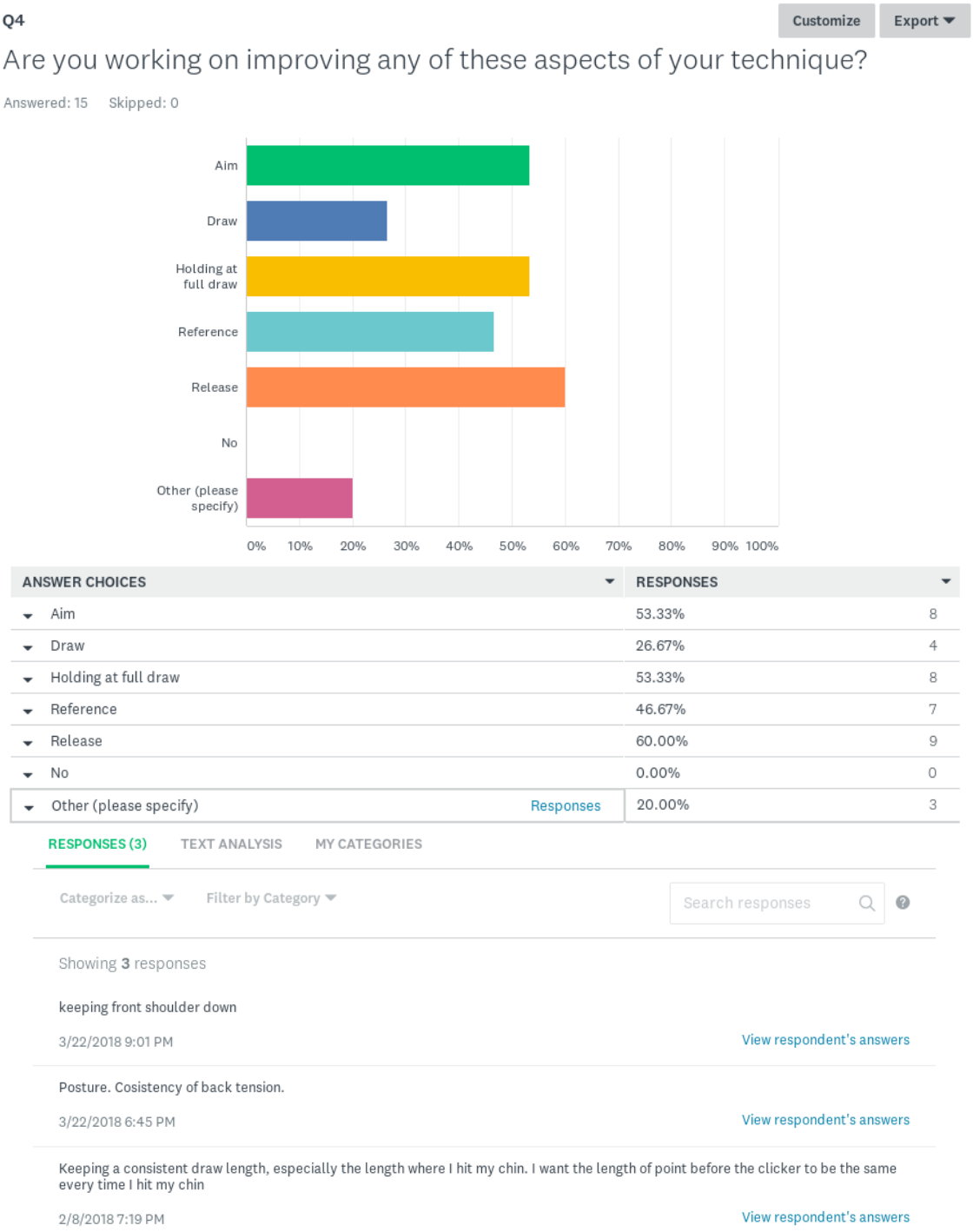


Figure 9 - Survey Questions 1-3

The next few questions focused on archers' experience in improving. A quick overview of the results confirmed what we had found with other research. Many people in the society are

looking to improve at archery. The problem space is quite broad, with people trying to fix a variety of problems in their technique. Interestingly, most people said they are working on improving their release, with an even spread of about half of the participants saying they are working on the other aspects. When considering how people are trying to improve, there was an expected high variation in answers. However, there was a noticeable trend towards the idea of increasing consistency as the main aspect of improving. We used this information to ensure that our application can allow tracking of performance over time so that users can check their consistency.



Q5

Export

If you are working on improving one of the above, can you tell us how you are doing so?

Answered: 14 Skipped: 1

RESPONSES (14) TEXT ANALYSIS MY CATEGORIES

Categorize as... Filter by Category Search responses

Showing **14** responses

Focusing on holding at full draw and relaxing fingers not flicking 3/22/2018 9:10 PM	View respondent's answers
lots of bow drills. 3/22/2018 9:01 PM	View respondent's answers
Trying to be consistent 3/22/2018 8:14 PM	View respondent's answers
Consistent practice/evaluation 3/22/2018 8:05 PM	View respondent's answers
A lot of practice 3/22/2018 7:08 PM	View respondent's answers
By making sure that each time i shoot, my technique is the same and I don't miss any step. 3/22/2018 6:46 PM	View respondent's answers
Trying to keep everything constant and only changing what I'm trying to improve. 3/22/2018 6:45 PM	View respondent's answers
Bow drills 3/22/2018 6:44 PM	View respondent's answers
Holding at reference 2/8/2018 10:58 PM	View respondent's answers
Trying to get the feel of it, it's hard to work on as I can't see it when I'm shooting. Getting coaches to look and tell me 2/8/2018 7:19 PM	View respondent's answers
Ensuring the hold is in exactly the same place every time, coming down if not. Making sure back tension is correctly applied. 2/8/2018 5:19 PM	View respondent's answers
Not that great. Working on them one by one. Trying to see what make me shoot better and trying to focus on improving that 2/8/2018 5:14 PM	View respondent's answers
By practicing before starting to shoot and then trying to be as consistent as possible. 2/8/2018 5:06 PM	View respondent's answers
Relaxing more as I release. Knowing the difference between a relaxed release and a tensed one 2/8/2018 4:48 PM	View respondent's answers

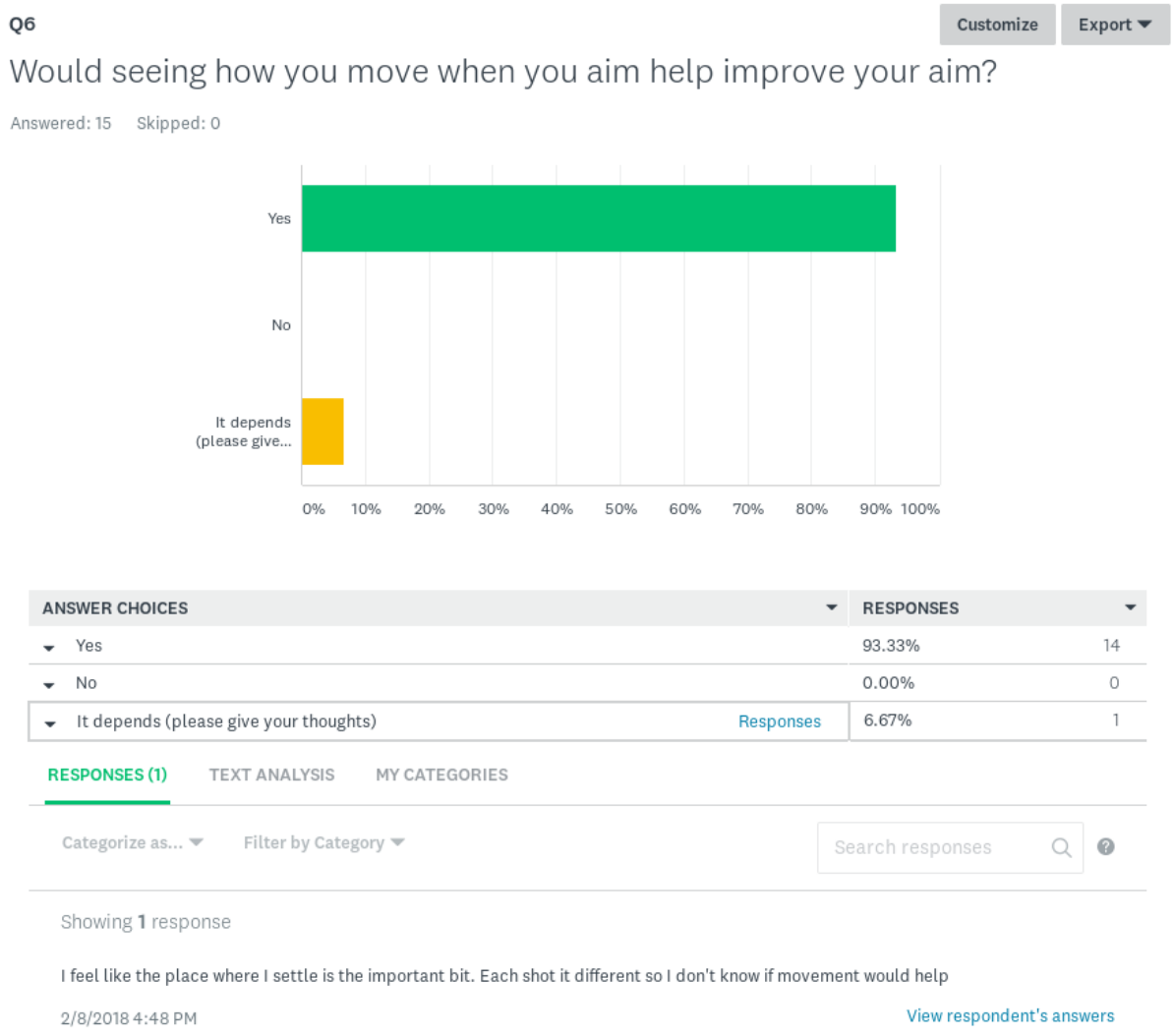


Figure 10 - Survey Questions 4-6

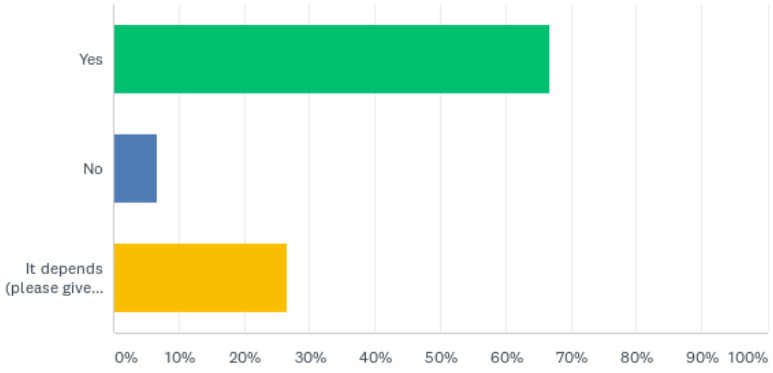
The final questions focused on shot tracking, with a question also dedicated to investigating if participants would accept using a physical device on their bow. Most participants said they would be up for using sensors on their bow to gather helpful data, given that the sensors do not affect the bow in any way. It seems that whether participants track their shots is dependent on if they are doing an event or specifically looking at their score. However, everyone agrees that they should track their score and placement on the face if they are looking to improve.

Q7

Customize Export

Are you okay with mounting external equipment on your bow?

Answered: 15 Skipped: 0



ANSWER CHOICES		RESPONSES	
Yes		66.67%	10
No		6.67%	1
It depends (please give your thoughts)	Responses	26.67%	4

RESPONSES (4) TEXT ANALYSIS MY CATEGORIES

Categorize as... Filter by Category Search responses

Showing **4** responses

Barebow so depends on whether it would affect the shot

3/22/2018 6:44 PM View respondent's answers

If it's not too heavy or bulky

2/8/2018 10:58 PM View respondent's answers

Depends how heavy the equipment is and where is placed

2/8/2018 5:14 PM View respondent's answers

Yes, as long as it doesn't affect my shot

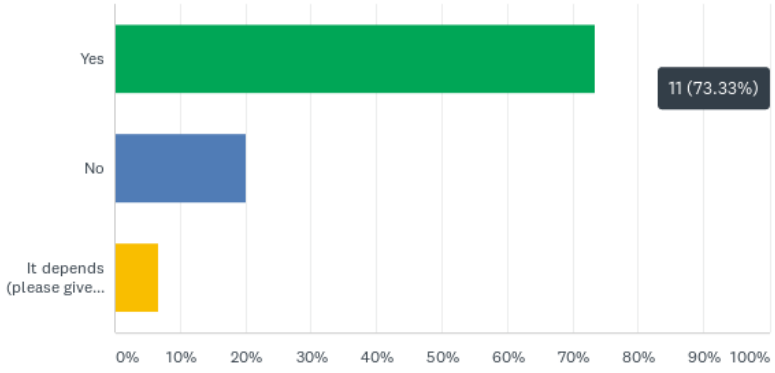
2/8/2018 5:06 PM View respondent's answers

Q8

Customize Export

Do you track where your shots hit the face?

Answered: 15 Skipped: 0



ANSWER CHOICES		RESPONSES	
Yes		73.33%	11
No		20.00%	3
It depends (please give your thoughts)	Responses	6.67%	1

RESPONSES (1) TEXT ANALYSIS MY CATEGORIES

Categorize as... Filter by Category Search responses

Showing **1** response

Sometimes I do, sometimes I don't. Depends of my mood on the day and how good I think I can shoot

2/8/2018 5:14 PM View respondent's answers

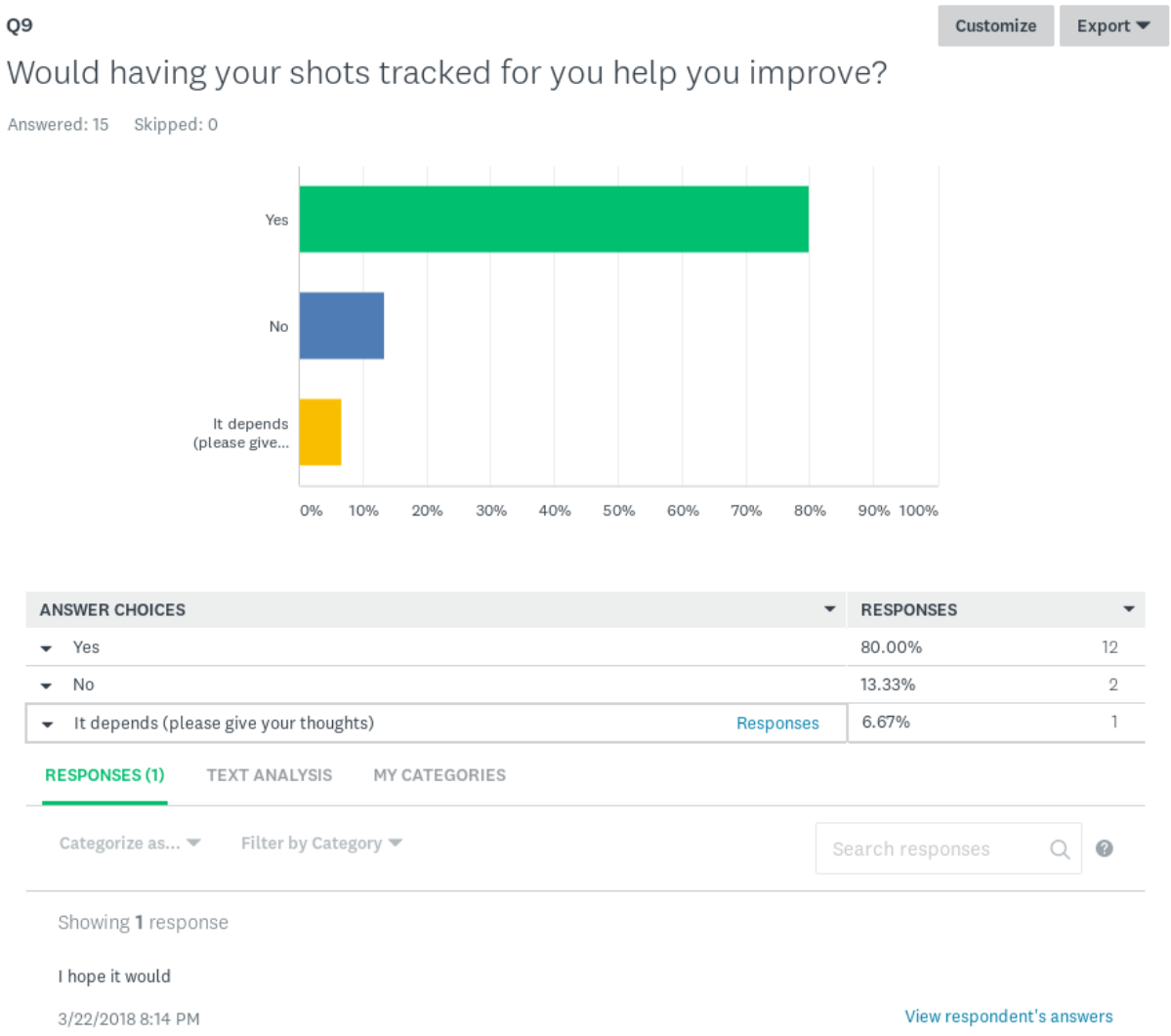


Figure 11 - Survey Questions 7-9

Interviews

We considered interviews with archers to help get more opinions on what our product should provide, and the problem(s) we should aim to tackle. We started with an informal discussion to get someone with experience to answer some preliminary questions.

We decided to take an iterative approach to interviews. We kept in contact with the archery society regularly, posing questions to them in an informal discussion. We were able to keep in regular contact with the archery society through the member of our team that attended archery sessions each week, and they conducted the informal discussion accompanied by team members when possible. Multiple archery members were involved in these discussions to provide a variety of answers and multiple perspectives on questions.

We learned multiple things from conducting our interviews this way. One is that the approach is quite effective, as staying in regular contact allowed queries to be answered quickly, as well as having consistent feedback. However, the informality can lead to loss of information and lack of formal report. Therefore, if this project were to be repeated, we would standardise the interviews we conducted and have them recorded for formal report and analysis, as well as archiving.

Field Study

Field studies allowed the group to visit the Archery society and observe sessions in action. This was important because it gave members of our team who had no experience with the sport prior to the project an opportunity to speak to members. We gained insights into their practices and saw first-hand what typically happens at a training session. Watching sessions in person gave us the chance to ask questions when we saw things we did not understand which is not possible with reading articles or watching videos. Reading articles and watching videos do have their own benefits such as being able to read and watch at any time that suits us compared to archery sessions which are scheduled on particular days. These methods supplemented each other in our research.

During the visits, we were informed of the safety procedures that anyone in the hall must follow and this raised some considerations that we have to factor into our designs. A key safety rule was based around two lines: a *shooting line* and a *waiting line* (which is behind the shooting line). The waiting line must be stood behind if you are not shooting and the shooting line is a line that anyone taking shots must not pass. No-one is allowed beyond the shooting line while shots are taken. This is so people do not accidentally get hit by arrows. A consideration from this is that if we want to place technology around the target then it must be carefully placed so that it is unlikely to get hit (although this will always be a risk of varying severity if anything is in front of an archer shooting).

After some conversations with the more experienced members of the society, we gained a better understanding of the bow structure and also how the archer interacts with each part of the bow. The bow is assembled at the start of each session and dismantled again for safe storage and carrying at the end of the session. Below is a labelled image of a recurve bow (which is a bow with a sight) and a labelled arrow.

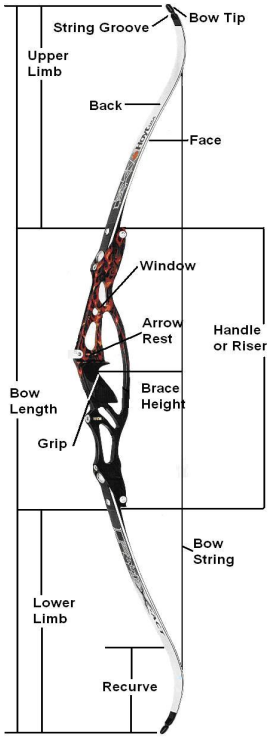


Figure 12 - Labelled Bow

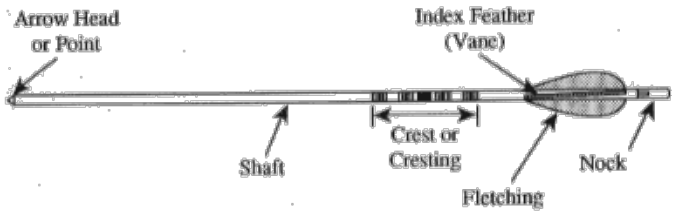


Figure 13 - Labelled Arrow

When an archer shoots, they hold the grip with the bow tilted forwards so they can access the bowstring easier. The arrow shaft is placed on the arrow rest and the nock is then positioned on the bowstring. The bow is then lifted to prepare the aim. Aiming is done based on eye-dominance so if the right eye is stronger then the riser is held with the left hand and the right hand pulls the bowstring back (and vice versa). Archers try to maintain a reference which is a consistent position that the bowstring is pulled back to, usually under the chin. After gathering this information, we noted potential positions on the bow that would be suitable to mount any sensors we felt could be useful. The riser seemed like a good position as long as it was beneath the arrow rest. This was because the arrow lifts immediately on release so if a sensor were on the upper section of the riser the arrow could hit it on release which is bad. We were warned against placing anything on the bowstring but that it may be acceptable if it is negligible in weight and certainly does not impede the use of the bowstring. This could be useful in training though for measuring tension of the bowstring and possibly arrow speed as a consequence. The limbs may introduce problems due to them flexing under the tension of the pull on the bowstring. It would be infeasible to attach sensors to the arrow because it would need to be done in such a way to not affect the flight of the arrow as well as making it resist the shock of hitting the target. A special arrow would have to be crafted that has any sensor embedded and this would make the product expensive.

We learned that developing archers struggle most with score consistency and are always trying to find ways to improve on this. This can be affected by many factors with stance, body motion during the shot, draw length (how far the arrow is pulled back) being the main ones. Some of these are easier to rectify than others and each archer will have a unique combination that works for them. It could be seen that only a handful of archers kept track of their scores and these were mainly the more experienced members of the society. This was done manually via a smartphone application or in a paper notebook. Many members of varying abilities responded positively to the thought of having a system track their shot performance for them. Some of the less experienced members of the society said that they sometimes found it difficult to improve when they were alone and that problems were only rectified when they were pointed out by more experienced members. They welcomed the thought of an automated system that could help them self-improve.

We agreed with the Archery society to return during our project to get feedback on designs so these initial field studies have been useful in establishing this study group. We have also gained a useful insight into how archery is done as a sport and will provide us with some considerations to factor into our problem specification and initial designs. The society shoots indoors so our we would have to make a decision on whether this could be extrapolated to outdoor shooting or not.

Personas

From the field studies, we developed a set of personas to aid us in deciding who our target audience should be. We decided as a group that our product could be used by archers of any skill level above absolute beginner. This reasoning came from the field study where we were informed that new archers would benefit more from human guidance to get started. Once an archer has gained a novice level of proficiency (regularly being able to hit the target with their shots - roughly 10 hours of shooting) they should be able to start seeing value in a system that could provide suggestions to them to improve further.

There is a spectrum of ability within the University society but from this we identified two major ability groups who would potentially get value from using our system: The experienced user and the average user. The experienced user is someone who has been shooting for a significant period of time (multiple years) and usually competes in competitions for the society. They may already have ways to track their shooting but this may be inefficient or rely on guidance from other people. The average user is less technically able but is in the process of learning to become better. The main problem at this level is consistency and there may be difficulty in identifying how to fix any problems. Tracking of performance is less likely compared to experienced users but may be interested in trying out new methods to make the next step in their performance. The developed personas for each are shown overleaf.

Experienced Archer

[8]

Name: Sophia Jones
Age: 23
Occupation: Student
Hobbies: Archery
Location: Birmingham, England
Tech Comfort: 8/10

“If I had a system where I could see more information about how I’m shooting as well as the scores then that would be valuable to me.”

Bio:
Sophia is a full-time student at Birmingham University and has a strong passion for archery. She takes part in many competitions representing the University and regularly aims for medal places. Currently she keeps track of her scores on a notes application on her mobile phone but this makes analysis of her scores inconvenient and she generally has to rely on the thoughts of other archers on the team which is a pain point for her. She wants to be able to have a system where there is more automation of how she is shooting and analysing when she took shots well and where improvements can be made. This should not be at a compromise for usability though.

Goals:

- Move away from manual note-taking of her shots
- More automation on the analysis of her shooting
- A system that’s easy to use

Frustrations:

- Time-consuming process for tracking her shooting
- Reliance on others for advice
- Inconvenient to analyse the scores written on paper

Average archer

[9]

s Area Roots | Sports | yankton.net." 29 Jul. 2011,
age_535b07af-aad0-5abf-9177-fc3b2c872cbd.html. Accessed 23

Name: Dave Daniels
Age: 22
Occupation: Student
Hobbies: Archery, Hiking
Location: Birmingham, England
Tech Comfort: 5/10

“I would love to be able to be more consistent with my shooting. Anything that could help with that would be beneficial.”

Bio:
Dave is in full-time education as a University student in Birmingham but in his free time regularly shoots in the University’s Archery society on weekends. He wishes to take part in more competitions but feels that his inconsistent shooting lets him down when it comes to placing well. He feels being able to track previous shots might help him to see his progress. The society is quite busy so it is difficult for him to be mentored. Therefore he has tried to use his smartphone to help him improve (through videos) with limited success.

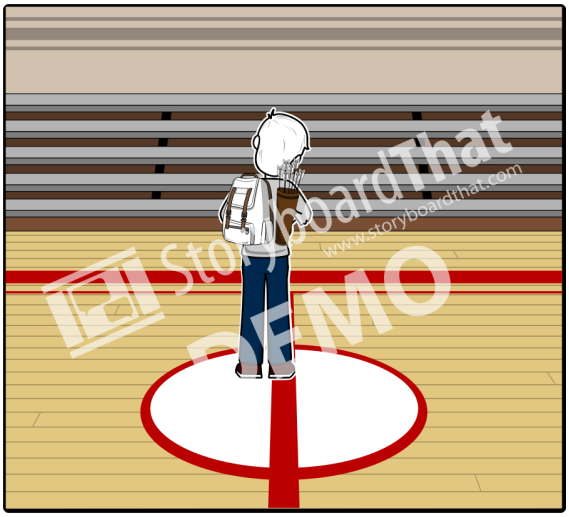
Goals:
- Become a more consistent shooter
- Win medals at competitions
- Keep track of his shots to analyse

Frustrations:
- Struggling to self-improve
- Not able to match previous scores against how he shot them
- Getting suggestions for improvement is difficult

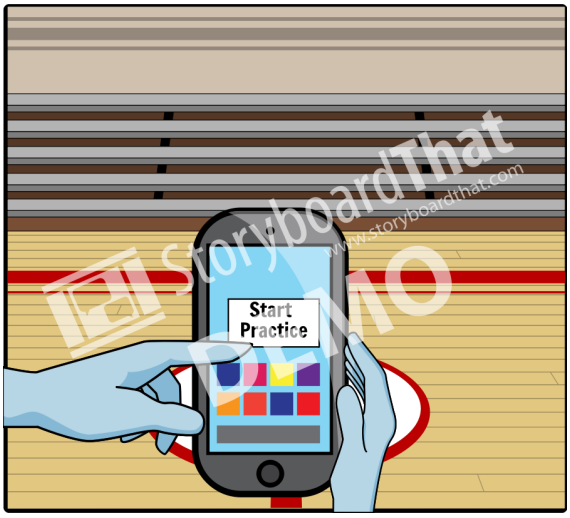
[9] "Archer taking shot stock image. Image of hunt, archery - 2157721." https://www.dreamstime.com/stock-image-archer-taking-shot-image2157721. Accessed 23 Jan. 2018.

Storyboard

The use of a storyboard summarises all of the research that we carried out earlier and tries to imagine a use case scenario for our product. When coming up with the storyboard we considered the field study to examine normal protocol during practice sessions and tried to reflect it within the storyboard. We also wanted to reflect the research into mobile interaction within the storyboard to show how the users would be interacting with their phone during the practice sessions when using our product. Considering all of this we storyboarded the normal routine of a typical target user for the product and produced the following:

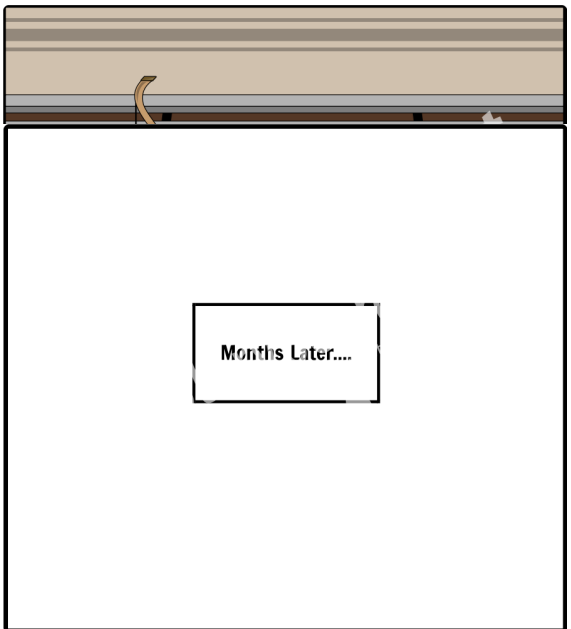


User goes to a practice session with disassembled bow and sensor kit. User sets up bow and attaches sensors as appropriate to start capture of session data.



User loads the application on the phone and connects sensors to the application so that it can capture the data from the session. Once the sensors are connected the user can click start practice and the application should be autonomous after that point, maybe also giving live feedback after each shot.

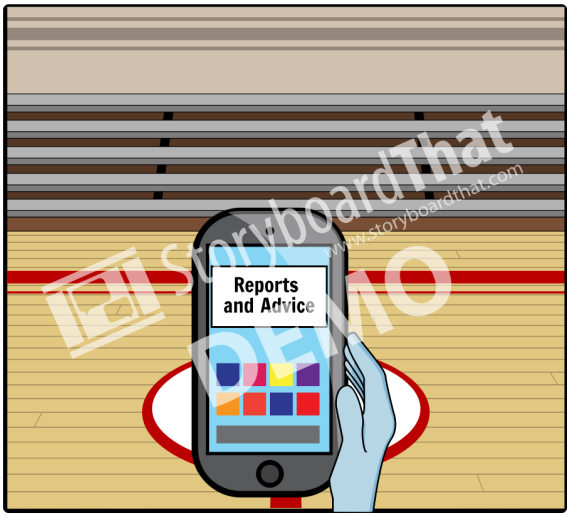
(Application layout in image not accurate)



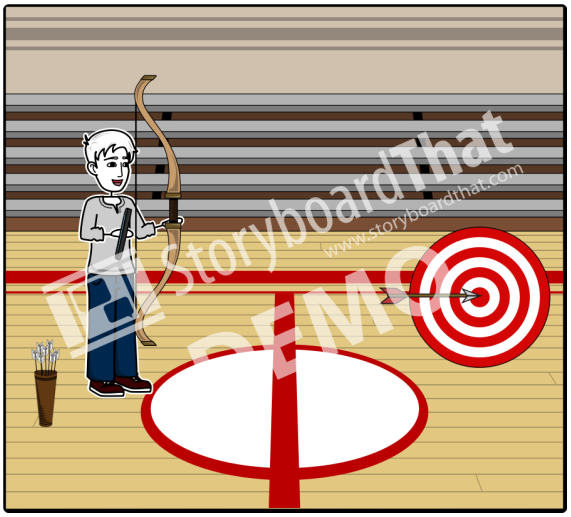
User can then start shooting and the sensors combined with the application will start collating the data. The user can check the application in between for live data or just carry on with normal practice with the application running on the phone in the background.

The user can check the application to see results of their shots, and other data from the sensors about their shots as well as analytics on what is causing errors and mistakes as well as advice on how to improve.

(Application layout in image not accurate)



The application will collate the data over months, storing it in a dedicated serve, and track users progress as well as providing analytics on strengths and weaknesses.



After the using the analytics and following the advice that the application provides, the user will start improving and producing more consistently better shooting.

Requirements

The research we carried out allowed us to narrow down the problem space and concentrate the focus of the project. We met as a group following the research stage to formalise the problem and agree our target audience for the product. The personas and storyboard that were developed from the research helped with this.

Problem Domain

We met as a group to consider our research and formalise a specification for our problem. The market research showed us that technology is being used to assist archery but this is predominantly a manual process. Carrying out an ethnographic study of the archery society revealed a lot of their practices and preferences and many seemed open to the idea of automating the way their performances are tracked. Due to the study taking place at an archery society that shoots indoors we decided that it would be best to focus on designing a system that works for indoor shooting (but could work outdoors if the conditions are similar to indoors e.g. little wind, no rain). This is because extra considerations would need to be made to account for the weather in calculations and making sensors more robust to the outdoors would make the product more expensive (e.g. waterproofing).

We decided that we wanted to primarily focus on how the archer moves when they are preparing to take a shot, how they interact with the bow and how this matches up with the score they achieve. This would then facilitate the production of suggestions that can be shown to an archer to help them improve. The research supports this as the questionnaire and field study both show that these are areas that archers wish to improve. We felt that it would be more beneficial to tackle issues around micromanagement of their shooting compared to other problems such as which bow they should use (barebow, recurve, compound) or bow size. This is because we thought that archers would either have their own bow which they have already bought or they will use society bows which they have little control over what they get. An archer will receive more guidance initially to get set up and shooting but once they start shooting it may be difficult to get such guidance regularly.

Part of the problem is also making the product inexpensive and accessible to archers of varying ability. This is important because many archers at the ability level we are targeting (see below) are likely to be hobbyists so may not be willing to outlay large amounts (especially if it is unaffordable).

Target Audience

The personas developed as part of the research have assisted us in identifying the target audience we wish to aim this project. We found that the two major groups that would get value from our system are “experienced” archers looking to refine their technique further and “average” archers who are trying to find ways to make their shooting more consistent. Other potential groups that exist within archery are novices (below average) and expert (above experienced). The reasoning for this is that the middle ability range is where most of the focus on broadly improving shooting technique will take place. Novices have a lot to focus on in the beginning from how to hold the bow and fire arrows so that the target can be hit from the required distance. Discussions with archers in the society informed us that it would take

around 10 hours of shooting for an archer to go from being new to where they could consistently hit the target. We felt that an archer with this experience would then start to get value from our product as they would have a feel for what may need improving and also how to act on the improvements suggested by the system. Once archers become expert level (regular competition winners at regional, national or international level) they may stop getting the same amount of value from the system as someone less experienced. This will mostly be down to their technique generally being so good that the product may not be sensitive enough to make the measurements necessary to give the improvements that this type of archer needs. This is due to a compromise on the amount we would want to charge for the product so that it is accessible by many. Also, experts are likely to have a dedicated coach (or be part of a coached team) who would do the job that this product does for them.

The experienced and average user may find that they are part of large groups with few mentors (this appears to be the case in the archery society) so getting regular advice on their shooting is not easy. If they were able to use a system that automatically tracked their shooting and provided feedback based on it then this would be valuable to them. This should prevent poor habits from developing which would happen if archers continued to shoot without any guidance. The research we have conducted supports this.

As we used the university's archery society as our study group the age of our audience will be in the 18-25 range and are well-educated.

Assumptions

The following assumptions were made about our users:

- Users own a smartphone
- Users are able to add sensors to their bow (providing it does not affect the usage of the bow)
- Users are able to install a mobile application that could accompany a solution
- Users will have access to the internet while shooting

Constraints

The project was subject to a series of constraints which affected what we could realistically achieve. The major constraints were time and money. We had 11 weeks to work on this project as a group so it was important that we were organised and managed our time well. This is because it is easy to be over-ambitious and to want to work on too many aspects at once and this could be more damaging than positive in such a short space of time. Finances were limited to £40 and this meant that any physical prototype would be restricted to the essentials necessary to show off our product idea. We would also have to wait for parts to arrive in the post and also ensure that they were compatible so that time did not get wasted waiting for more parts to arrive.

This was the first project that any of us had taken on relating to the Internet of Things so there is the initial overheard of learning how to create systems within this paradigm and we would have to learn quickly in order to not fall behind with the project. The small group size limits the scope of what can be achieved but we aim to generate a lot of ideas that could be pursued should a suitably equipped team take it on.

Functional Requirements

- The system should allow an account to be created
    - The account should have a unique user name, such as email
    - The account should have a password
- The system should allow users to sign into their account
- The account should allow users to sign out of their account
- The system should enforce that users are signed into their account
- The system should monitor how the archer aims their bow
- The system should be able to detect when the archer releases an arrow
- The system should be able to detect when the archer starts aiming
- The system should display how the archer moves against a standard baseline
- The system should allow any sensors to be calibrated before use
- The system should monitor where the arrow has hit on the target
- The system should be able to record scores on multiple shots
- The system should be able to store the scores for the archer to track
- The system should be able to display stored scores and past data
- The system should be able to provide suggestions on the archer's technique
- The system should be able to populate a spreadsheet with data related to that archer's shooting

Non-Functional Requirements

- The system should be able to be mountable on a bow
- The system should record data about the shot within a short time frame (a few seconds)
- The system should not obstruct the usage of the bow or the bowstring in any way
- The system should not add significant weight to the bow
- Multiple systems should be usable in close proximity
- The system should be wireless for convenience
- The system should work without the application being open on the phone
- Data relating to users should be stored and transmitted in a secure manner
- The system should be robust and not prone to failure

Develop & Deliver

Initial Designs

After the requirements have been finalised, the next stage would be designing the product itself. The design of the product would satisfy the requirements specified in the previous section, to confirm it meets the objective and the purpose of the product. Before coming up with a final design, we should first explore the problem space.

Exploring the Problem Space

The problem provides a lot of scope for exploration within the problem space and we looked at many features which could be included. Each feature was considered in detail to discover what different options there were to solve that requirement. We decided the best way to formulate this was by taking our list of requirements and describing alternative solutions to each. We also considered using the Question, Option, Criteria methodology to explore the problem space but we thought this was unnecessary as it would effectively be a restructuring of our requirements. Below is a discussion of the alternative solutions we considered.

Exploring the Requirements

The system should allow an account to be created. The account should have a unique user name, such as email. The account should have a password.
This could be done via a desktop PC, laptop or mobile phone. Due to the nature of archery it is unlikely that anyone would bring a PC or laptop because of space and time restrictions (nowhere to set one up effectively and the archer would be regularly shooting). This means any interface that an archer uses while at a session would most likely be through a mobile phone so this would probably be the most effective way to enable account creation. This requires the archer to have a smartphone but this is a safe assumption with many young adults owning one. Of course, account creation could be done at home where access to a PC or laptop is available so a website could be created to provide a platform for creating accounts but this would not be a priority (as the mobile application can cover the requirement more flexibly). Sign in could be done through a source such as Facebook or Google where the archer uses one of those accounts to create an account with our system. This would give us the benefit of us not needing to maintain the user's account details as the verification would be done by the third party.

The system should allow users to sign into their account. The system should allow users to sign out of their account.
This can be done most easily via a mobile application. Explanation is similar to above.

The system should enforce that users are signed in.
We decided that if a user is going to use the product, that it would be easier to segregate data if all data that was collected was against a user account that was signed in during the session and to maintain a history of sessions. Considerations were made to allow guest users and make it so that any data and suggestions produced for a guest session would be destroyed at the end of that session. We felt that this would not be valuable because a user using this system will probably have exclusive use of it (or if it is shared then each user

would want their own individual tracking) so enforcing that the user is signed into an account is reasonable. We also found out from the archery society that bows are rarely shared due to them needing to be set up and adjusted differently for each archer so having guest shooters would not be that used.

The system should monitor how the archer aims their bow.
This can be achieved by tracking the archer directly or the bow itself. Motion sensors could be attached to the archer to track how they move and this could be matched against the scores they shoot. Doing this would require a lot of sensors on different parts of the body in order to capture the motion of the archer. More sensors would provide a clearer indication of how the archer is moving. This would be a tremendously difficult approach to take up due to the need to coordinate the data from each sensor and would be time consuming to do. Each archer is different and this would lead to a unique setup (and potentially different number of sensors). This becomes infeasible quickly and would also be an expensive approach in needing to fund the sensors.

Another solution would be to use a video camera. This would allow footage to be captured of the archer's motion as they take their shot. We realised that this would be difficult to do reliably due to the need to analyse a moving image. This would be even harder if it were recorded in a low resolution which would be likely with a cheap video camera. Tags or stickers could be used to help focus the video but this would mean the archer needing to apply the stickers to themselves and keeping them facing the camera which is not ideal. There are also issues around storage and privacy with video (de-anonymising the video would be essential). Archers we spoke to at the society said they would probably not set up a camera to record themselves shoot as it made them feel uncomfortable.

A better approach would be to attach sensors to the bow and measure the motion of the bow as it takes shots. This is good because the bow will move as a direct action of the archer so we are still in essence capturing how the archer moves but through the bow. Bows do not differ much within their class (barebow, recurve etc.) so sensor placement could be done consistently and with less difficulty. Accelerometers and gyroscopes are sensors that can be used to measure the motion of the bow. An accelerometer measures linear, non-gravitational acceleration through vibrations and gyroscopes measure orientation in the world by using the Earth's gravity to work out which direction is 'down' and towards the centre of the Earth. This is done by measuring angular velocity around an axis. There is a sensor called an Inertial Measurement Unit (IMU) which can do both of these tasks and there are ones available for use within the Internet of Things. The benefit of this is that the sensor should be small and with it being packaged into one sensor, it should mean that less surface area is taken up on the bow. The problem with these sensors is that they are likely to be noisy and it is not clear whether they factor out gravitational acceleration so this will need to be factored out if necessary. Despite that we feel this would be the best method for tracking how the archer aims.

The system should be able to detect when the archer releases an arrow.
The IMU mentioned in the previous paragraph would be capable of detecting when an archer releases an arrow. This is because the bow goes through a specific motion when a shot is taken. When an archer prepares a shot, they lift the bow up high in a straight, swift motion. They then slowly lower the bow stopping it when they are happy with the positioning.

This is because it is easier to aim this way rather than slowly lifting the bow up to the required position which can be more tiring. The archer then draws the arrow and when it is released, the bow tips forwards noticeably as a reaction to the bowstring releasing the arrow. This motion should be detectable by an IMU and would require no further sensor support if the IMU is used in the solution.

Figure 14 - Archer firing an arrow and the bow tipping forwards[10]

Alternatively, a strain gauge could be used to ascertain when an arrow is fired. These work by varying the electrical resistance against applied force. This means that tension on the bow can be calculated based on the change in electrical resistances. A sudden change in tension would indicate arrow release. A strain gauge would also have the advantage of being able to record how far back the bowstring is drawn by the archer. This could be used to indicate how consistently the archer is drawing their arrows. This would not be feasible to put on the bowstring as it would affect the way arrows are drawn but it could be fitted on the riser or limbs if there is sufficient space. We decided to leave the strain gauge out of our initial designs but there is potential scope for it in future versions due to the extra information it provides.

The system should display how the archer moves against a standard baseline.
A smartphone application can be used to show this information to the user and would be the easiest method especially if other requirements are integrated within the mobile application. This has the benefit of being more personal to the user as they would have control over who sees the information (i.e. who they show their phone to). The standard baseline could be a baseline we set as what a typical archer should aim for or there could be the option to allow an archer to set their own target baseline. Both of these options would suffice and having the option gives flexibility and choice to user. Alternative displays could be static images of graphs that could be attached to the account to view from a PC or emailed to the user. This is less desirable because the archer may not be able to check their performance back within

[10] "BUCS Indoor Archery continues to see participation grow & records fall." 8 Feb. 2016, https://www.bucs.org.uk/news.asp?itemid=19656&itemTitle=BUCS+Indoor+Archery+continues+to+see+participation+grow+%26+records+fall&section=8&sectionTitle=News. Accessed 21 Mar. 2018.

a reasonable time frame. Using email to send graphs may be cumbersome and also would be difficult to secure as emails are generally unencrypted.

The system should allow any sensors to be calibrated before use.
This can, again, be initiated through a mobile application to tell the sensors to calibrate once they are fitted to the bow. This would be easier and could be done as often as the archer needs. This would be better than having the sensor wired up to a laptop which would be obstructive and also a long cable would be required to reach.

The system should monitor where arrows hit the target face.
We discussed multiple ways of tracking where shots land on the face. The most user involved method involved having a picture of a target face on the phone, and the user places where on the picture their shot landed. This is similar to the MyTarget app. The method has the potential to be inaccurate if the user does not effectively put their shots in, and also requires effort from the user to get their phone out each end, navigate to the page and put in the data before collecting their arrows.

The most system focused method would involve having a camera placed on the floor in front of the target with the full face in view, and would accurately place the shots on a picture of a face through using image processing. This would be done automatically, and requires no involvement from the user besides set-up. However, there is the potential for the camera to be hit and damaged, and the camera may not be able to be used in rainy weather, depending on the model, if we scaled to outdoor use. Image processing is notoriously tricky but the strong separation in colour of the target would make it possible to differentiate colours. The difficulty would be in determining score boundaries as the circles that divide these are fainter. A high resolution photograph would be needed for this.

The middle-ground solution would be to have the user take a photo of the face at the end of their shots, and have the system do image processing on the picture. This would require little effort from the user, and would not require a camera to be constantly in action. However, the user would need to make sure the picture is valid. This can be done by rejecting invalid photos and/or providing on-screen guidelines for the user to line the face up with.

The system should be able to record scores for multiple shots.
This can be tracked manually or automatically. The manual process would be for the user to tell the system (probably through a mobile application) when they are taking each shot. This is not ideal because the archer will not put their bow down in between shots, they will most likely take all of their shots for an end (set of shots) and then put their bow down after that. This means an automatic approach where the system can determine when each shot is being taken would be ideal. If this proves too difficult then the measurements could be done per end and then averaged over the number of shots in the end.

The system should be able to store the scores for archers to track.
Multiple solutions exist for storing data. Data could be sent and stored directly on a smartphone. This would have the benefit of not having any middle hardware and data could be transmitted direct. This would mean that the smartphone would have to coordinate the data processing whether it is done on the phone or sent to the cloud. This relies on the smartphone maintaining all of the connections to the sensors which would be power

consuming. An alternative solution would be to have a dedicated server which connects to the internet and have sensors that also connect to the internet. The data is transmitted from the sensors to the dedicated server and the server would then do any necessary processing there. Data can be stored in a database on the server. This server could be a Raspberry Pi which is small, cheap and convenient. The Pi could be stored at home or brought to sessions as long as it had a source of power. The smartphone would then act purely as a display of information and data would be transmitted from the server to the smartphone. This frees up processing on the smartphone saving battery on it. This setup may be slightly more complex but it offers more flexibility to the archer.

The system should be able to display stored scores and past sessions
Similar to previously mentioned, a smartphone application can be used to display this data. Emails and PC applications are an alternative but would be cumbersome to use when this data may be wanted on a whim.

The system should be able to provide suggestions on the archer's technique
Similar to previously mentioned, a smartphone application can be used to display this data. Emails and PCs can be used like above too.

The system should be able to populate a spreadsheet with data related to that archer's shooting.
A spreadsheet would allow the archer to view more of the fine-grained details of how the suggestions were produced and they could review them to get a deeper analysis themselves as well as the ones we provide. Exporting to spreadsheet could be done in many popular formats such as Microsoft Excel or Google Sheets. Using Google Sheets would require the archer to be signed in with a valid Google account.

Considerations were also made over how to carry out the communications between sensors and receivers. The first option is a WiFi Arduino Module. This method allows the Arduino Nanos to communicate data wirelessly over the internet. All data is transferred over the internet. This has the benefit of wires not being required to connect to a server so this means the server does not have to be geographically close. Wires could also potentially obstruct the usage of the bow if they are positioned poorly. Wireless transmission is difficult to set up and this may require the use of extra microcontrollers to coordinate the transmission which would add an extra layer of complexity. Another option is a Radio Transceiver Module. This method communicates data wirelessly through a radio transceiver module. This will require a second Arduino Nano communicating with the sensors on the bow as well, and the second Arduino Nano connected to the Raspberry Pi. Wireless communication in this system has a very limited range and requires extra equipment to store the data. This seems like it would be a similar amount of effort as the wireless setup for no extra gain. The simplest solution is to use a wired connection and this would be the easiest to set up. This method connects all the subsystems together through wires. This would be inconvenient to have so many wires that need plugging in as part of the setup and may restrict where the archer can stand unless cables are sufficiently long. The wireless set up would be the best out of these three.

The archery society at the University is an indoor shooting society so the design considerations will mainly be factored for indoor shooting. However, the design could be extended to outdoor shooting if necessary. More consideration would be needed on aspects

such as the weather (rain and wind being the major obstacles). It may also be difficult to maintain the necessary internet connections while shooting outdoors too so internet tethering or hotspot creation may be needed but this would be up to the user which is an inconvenience for them.

As a group we considered whether we should target individuals only or groups of archers and allow for more collaborative sessions. We decided it would be more beneficial if we targeted individual users because each archer shoots in their own way and will need their own tailored feedback and advice. The system could be used by a coach to tailor how a coach teaches an individual based on how they perform too. Speaking to members of the archery society confirmed that any tracking they had done in the past was mainly on an individualistic basis and this is something they would prefer to maintain.

Brand Design

Having already decided on the brand name as ARCHiE, we wanted to explore ideas on how we could develop the brand further with a logo.

Before starting to design the logo we decided a colour scheme to use as part of the logo. At first we thought we would use the colours on the target face as this would be fitting with the Archery theme and would also be memorable to the viewers eyes making the overall brand memorable.

Next we researched into a few different existing logos to see what we thought was good and bad between them and use it to decide which features we wanted to replicate within our logo. Here are a few of the logos that we looked at:

Figure 15 - Collection of Logos

From these logos we decided that a main element that we would need to consider is the typography, all the logos above use simple fonts, which also make them memorable. We also realised that a simple icon would be useful as part of the logo as it would make the logo more memorable as well having a part of the logo which we can use as a separate entity in various places. We also agreed that we like the subtle icon of two people sharing a Tostito in the Tostitos logo so we would also try and replicate this within our logo.

Considering all of these ideas, these are the initial ideas that we produced:

1)

2) 

3) 

4) 

After these initial ideas we discussed what we liked and disliked about each and what we should go forward with. The team decided that we like the font used in the 4th concept, however we did not like the arrow used in the icon and decided it would be better to use a more realistic arrow icon. Also, we realised that we did not like the colour in the logo as it makes the logo appear quite childish and novel, so we decided to revert to a black and white logo.

Another idea that we came up after these initial ideas was the use of tagline for the brand. We came up with “Track, Analyse, Improve”. We thought that this is a strong tagline as it is short and simple making it easy to remember and employs the technique known as the rule of three.

With all these ideas in mind we came up with a final design for the logo:

Figure 16 - Final ARCHiE Logo

System Design

IoT Architecture

Our initial design consists of an accelerometer and gyroscope module (an IMU - Inertial Measurement Unit) attached to the bow to monitor the movements of the bow. The system consists of the module connected to an Arduino Nano which is attached to the bow. The Arduino Nano will also have a WiFi transceiver module attached to it which allows it to communicate with the Raspberry Pi directly and wirelessly.

The sensor module will provide information on an object's orientation, acceleration, etc. This data can be used to determine what suggestion to provide to the archer. For example if a value is over a certain threshold, give a suggestion to the archer that they can see on the mobile application which may fix this. Learning could be implemented to calculate if the archer has any trends or 'bad habits'.

To record the scores, we have decided to use a camera to capture the face. The camera will capture colours of the face to determine where the arrow has hit and record the score which the archer achieved. Likewise, the images will be captured and sent to the Raspberry Pi for image processing through a second WiFi module and a second Arduino Nano. The Raspberry Pi itself may not have good enough performance and therefore will require other ways to do image processing. It could send the images to the cloud for processing and then the analysis are sent back. Once the scores have been calculated, this can be recorded and stored on a spreadsheet on Google Drive. This allows the archer to track their progress from anywhere, including on their PCs at home, and not just from their mobile phones.

The system will have a mobile phone application which will receive results from the server, including how the archer has shot, and suggestions for improving on the archer's techniques. Details on the functionalities of the mobile phone application will be described later in this document.

The security of the system is important and most of the archer's data would either reside on the Pi or within a Google Drive spreadsheet (potentially at the user's choice). When transmitting data out of the Pi, encryption could be used to make data difficult to read if intercepted. Security would mainly be for ensuring privacy (although for the average user it is unlikely they will be targeted for their archery data but the principle is important to gain trust).

Since our system is composed of multiple independent subsystems connected to a central Raspberry Pi server. If one of these subsystems stops working, the others would not be affected. The failure of a subsystem would negatively impact the performance of the overall system, however such an issue could be easily solved no matter which part of the system fails. For instance, if the mobile application stops working, the user would still have all their data sent to the Google spreadsheet, therefore their data would not get lost. If one of the sensors stopped working, then the user would still get info from all the other sensors. The main issue would be if the Raspberry Pi failed because then no data would be recorded. There would need to be some mechanism for informing the user if this happened such as displaying on the mobile application or the spreadsheet that they lost connection to the Pi.

The following structural diagrams were made to help us to understand our product and make it more clear what needs to be implemented:

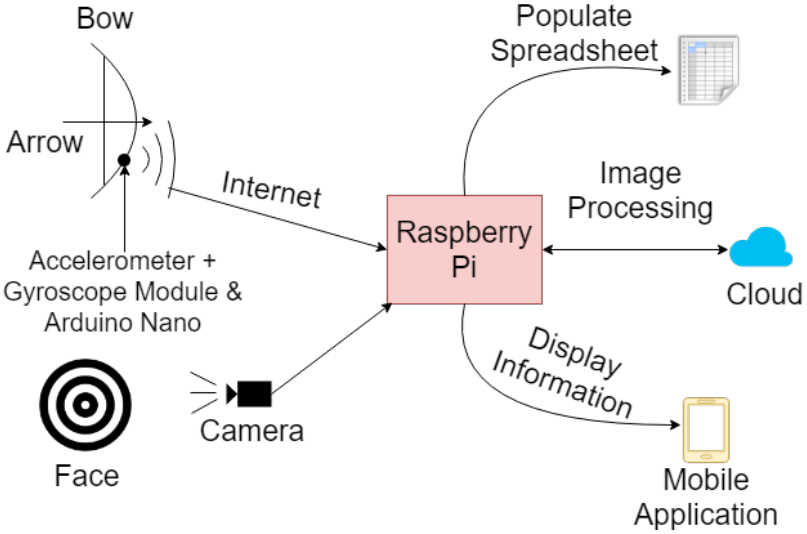
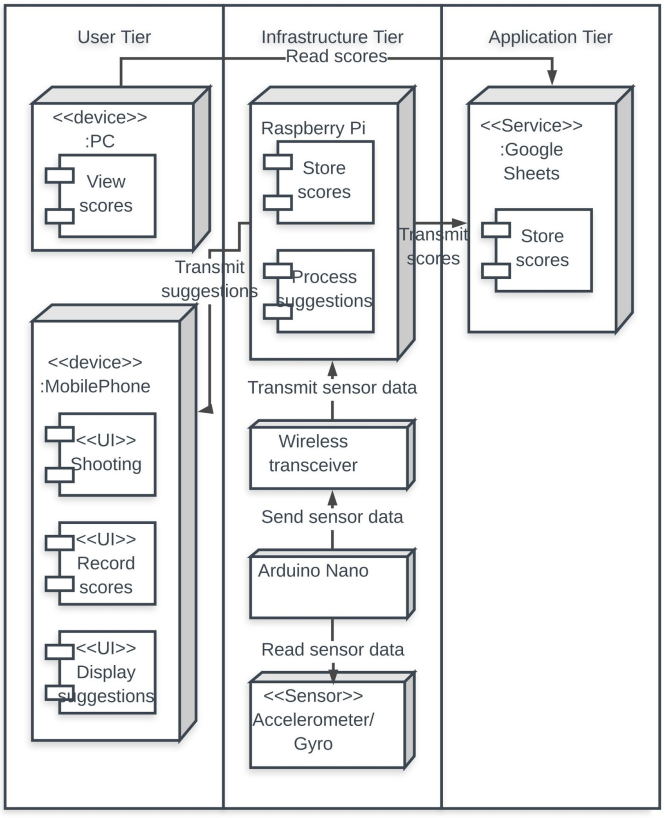


Figure 17 - IoT Architecture Structure Diagram



A camera can also be added as a sensor to record scores. This can be connected via an Arduino and Wireless transceiver in a similar manner to transmit to the data to the Pi.

Figure 18 - Deployment Diagram

Mobile Application

The first version of the mobile application is a rough first draft, a very minimalistic design. The main idea behind the first version was to brainstorm and understand what the most important parts of the application should be. From this version we realised that having an informational screen while the user is shooting could be helpful. For example, if the archer is far away from the target, they could use this screen to check where their arrow landed instead of having to walk all the way to the target face. We realised that allowing the user to choose their own shooting options would make the application adaptable to any needs, instead of having to decide on what the best shooting options could be and never allow the user to customise them.

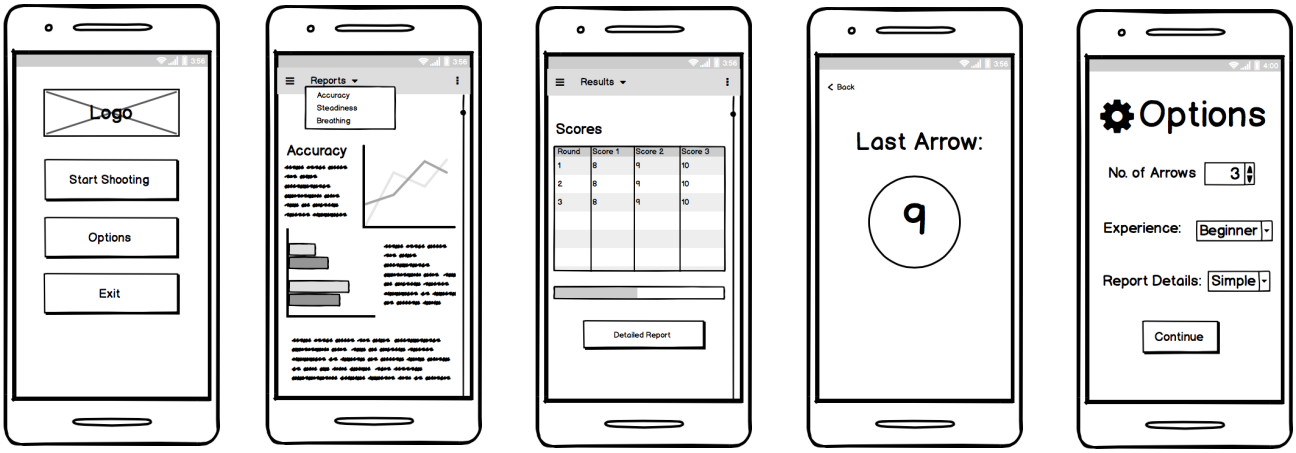


Figure 19 - First Draft of Mobile Application UI

Suggestions Algorithm

The algorithm providing suggestions based on the sensor data is undoubtedly one of the hardest part in the system. As the sensor data read are relatively noisy, this can be reduced for a more accurate result from the algorithm. This can be done through smoothing data values by a moving average filter[11]. A moving average filter works by taking several values

[11] "The Scientist and Engineer's Guide to Digital Signal Processing ...." http://www.analog.com/media/en/technical-documentation/dsp-book/dsp_book_Ch15.pdf. Accessed 21 Mar. 2018.

at once and taking the average of them. Below shows a graph of noise being reduced by taking the average out of 11 values. These smoothed out values will then be fed into the algorithm provided below.

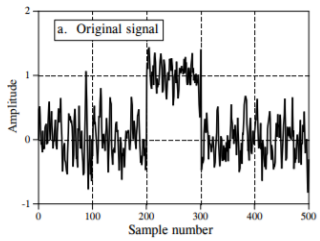


Figure 20 - Before Smoothing

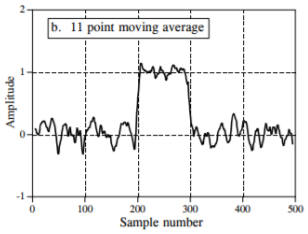


Figure 21 - After Smoothing

```
//current position is n
//each array contains values at position n-2, n-1, and n respectively
//"roll" value contain value at position n (current value)
static int PREVIOUS2 = 0;
static int PREVIOUS = 1;
static int CURRENT = 2;
float[] yaw = new float(3);
float[] pitch = new float(3);
float roll;

float yawP2PDiff = yaw[PREVIOUS2]-yaw[PREVIOUS];
float yawPCDiff = yaw[PREVIOUS]-yaw[CURRENT];

//if bow is moving left and right too much
if((yawP2PDiff > 1.0 && yawPCDiff < -1.0) || (yawP2PDiff < -1.0 && yawPCDiff > 1.0) {
    System.out.println("Moving left and right too much!");
}

float pitchP2PDiff = pitch[PREVIOUS2]-pitch[PREVIOUS];
float pitchPCDiff = pitch[PREVIOUS]-pitch[CURRENT];

//if bow is moving up and down too much
if((pitchP2PDiff > 1.0 && pitchPCDiff < -1.0) || (pitchP2PDiff < -1.0 && pitchPCDiff > 1.0) {
    System.out.println("Moving up and down too much!");
}

//if bow is angled more than 5 degrees
if (roll < -5.0 || roll > 5.0) {
    System.out.println("Tilting the bow too much!");
}
```

Figure 22 - Suggestions Algorithm Pseudocode

Languages and Frameworks

As the main sensor modules are wired to Arduino Nanos, we used Arduino's default IDE and programming language. The development code can be easily verified and also uploaded to the physical board, which makes the process more convenient. The IDE is lightweight and very easy to use for Arduino beginners. Other programming languages for the Arduino board will require a different compiler for the chip with a series of built-in functions.

Once the code have been uploaded to the board, a Java program can interact with it utilising the SerialPorts library. This allows us to create a simple GUI which could show more information about the sensor or a program which can process the information. Java[12] is used as it is a programming language which we are most practiced in. Other programming

[12] "Java Arduino GUI - Let's build!." 18 Sep. 2017, http://www.buildtech.xyz/2017/09/18/java-arduino-gui/. Accessed 20 Mar. 2018.

languages can interface with the Arduino as long as they have a way to communicate with the Arduino through serial ports.

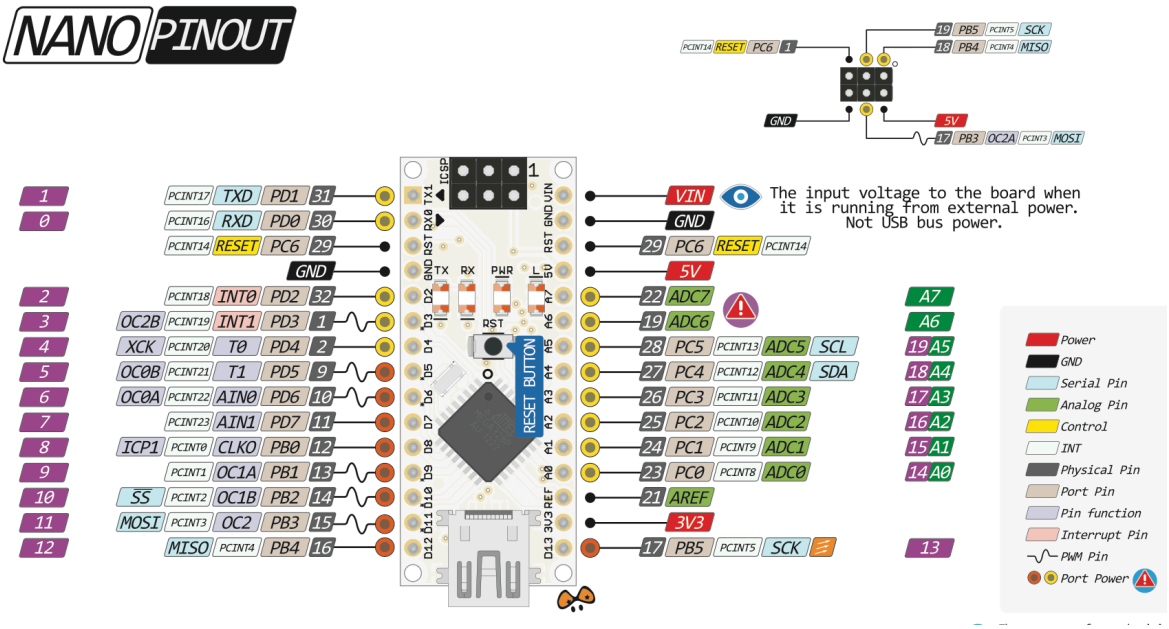
Prototyping

The next step was to develop a prototype which shows the Proof of Concept (PoC). The PoC will show basic functions of the system and a clear idea how the system will scale. The prototype will primarily be based on the initial design specified earlier, while looking for opportunities to improve the design.

System Design

IoT Architecture

The development should start small and slowly scale up, adding more and more to it. Our first step is to make sure the sensor module works and prints out digital values. A piece of example code from the MPU6050 library demonstrates this function and prints out raw values for yaw, pitch, and roll. The difficult in this part was connecting the sensor module to the Arduino Nano. Although there were several online tutorials on which pins go where, they are different, therefore it took a bit of time tinkering around the jumper wires, making sure they were plugged into the right place. The pins which worked were 3V3, ADC4 (SDA), ADC5 (SCL), both GND, and INT0[13]. However from the printed values, we learned that the values are raw and has no reference point in terms of its yaw, pitch, and roll, therefore we



will need to implement some form of calibration before the analysis[14].

Figure 23 - Arduino Nano Pinout

Further research uncovers a simple calibration algorithm for the sensor module. This algorithm takes several readings from where the sensor starts and outputs offset values which the module should initialise with. Both pieces of code were merged together into one

[13] "How to Interface Arduino and the MPU 6050 Sensor - Maker Pro." https://maker.pro/education/imu-interfacing-tutorial-get-started-with-arduino-and-the-mpu-6050-sensor. Accessed 02 Mar. 2018.

[14] "Calibrating & Optimising the MPU6050 – chillibasket." 21 Jan. 2015, http://wired.chillibasket.com/2015/01/calibrating-mpu6050/. Accessed 08 Mar. 2018.

where now it would output values for position change based on its initial position. A major challenge when merging the code was the different libraries. Some of the code had methods which one library had and the other did not. We had to recode some parts of the code so both sections would use the same library. These values were printed out on the computer which the Arduino Nano and sensor are wired up to. This is as far as the physical prototype goes.

```
void calibration(){
  ax_offset=-mean_ax/8;
  ay_offset=-mean_ay/8;
  az_offset=(16384-mean_az)/8;

  gx_offset=-mean_gx/4;
  gy_offset=-mean_gy/4;
  gz_offset=-mean_gz/4;
  while (1){
    int ready=0;
    accelgyro.setXAccelOffset(ax_offset);
    accelgyro.setYAccelOffset(ay_offset);
    accelgyro.setZAccelOffset(az_offset);

    accelgyro.setXGyroOffset(gx_offset);
    accelgyro.setYGyroOffset(gy_offset);
    accelgyro.setZGyroOffset(gz_offset);

    meansensors();
    Serial.println("...");

    //get the mean value and calculate the offset based on what it should be (i.e. zeroing it)
    if (abs(mean_ax)<=acel_deadzone) ready++;
    else ax_offset=ax_offset-mean_ax/acel_deadzone;

    if (abs(mean_ay)<=acel_deadzone) ready++;
    else ay_offset=ay_offset-mean_ay/acel_deadzone;

    if (abs(16384-mean_az)<=acel_deadzone) ready++;
    else az_offset=az_offset+(16384-mean_az)/acel_deadzone;

    if (abs(mean_gx)<=giro_deadzone) ready++;
    else gx_offset=gx_offset-mean_gx/(giro_deadzone+1);

    if (abs(mean_gy)<=giro_deadzone) ready++;
    else gy_offset=gy_offset-mean_gy/(giro_deadzone+1);

    if (abs(mean_gz)<=giro_deadzone) ready++;
    else gz_offset=gz_offset-mean_gz/(giro_deadzone+1);

    if (ready==6) break;
  }
}
```

Figure 24 - Main Calibration Function

```
// display Euler angles in degrees
accelgyro.dmpGetQuaternion(&q, fifoBuffer);
accelgyro.dmpGetGravity(&gravity, &q);
accelgyro.dmpGetYawPitchRoll(ypr, &q, &gravity);
Serial.print("ypr\t");
Serial.print(ypr[0] * 180/M_PI);
Serial.print("\t");
pitch = ypr[1] * 180/M_PI;
Serial.print(pitch);
Serial.print("\t");
roll = ypr[2] * 180/M_PI;
Serial.println(roll);
```

Figure 25 - Main Printing Function

From here, further stages of iteration would be using the laptop as the Raspberry Pi which processes the information with the “Suggestions Algorithm” described in the section below. The next iteration after would be using the wired laptop as a wireless module and communicate with a Raspberry Pi. The actual wireless module can then be attached to the

Arduino at the end so that it is configured to send the sensor data to the Raspberry Pi, slowly building towards the design specified earlier.

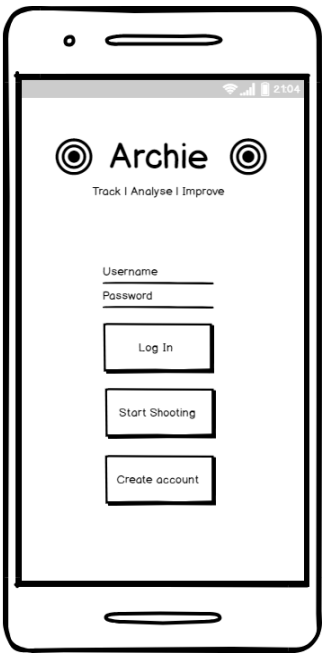
Due to time constraints, there will not be a camera tracking the score. Instead we adopt the method of manually tapping the phone screen to pinpoint where the arrow has shot. This feature is described in the “Mobile Application” section below. Although strain gauges were not in the initial design, strain gauges are able to collect data on the draw length of the archer. We believe this allows the program to provide more accurate and different suggestions and at the same time satisfying our defined requirements. The strain gauge could only be attached to the riser or the limbs of the bow.

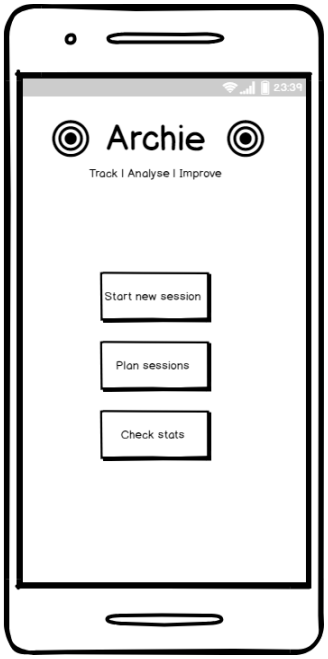
Mobile Application

During the development of the mobile application, a lot of factors would have to be taken into account, such as making the application easy to use, keeping a simplistic layout, using colours and icons to make it attractive, not overwhelm the user with a lot of information at once and instead split it across multiple menus, not rely on the user to remember how to use the application, give the user the kind of information they want, etc. To make sure the design of the application would fit with the needs of our targeted users, we have stayed in contact with the members of the archery society and held informal interviews and polls. After each step of the design we have produced a physical PoC that would allow the members of the society to have a realistic interaction with our application, which would produce a higher quality and more accurate feedback. By using this feedback, changes would be made to the application and then these changes would be checked with the members from the society.

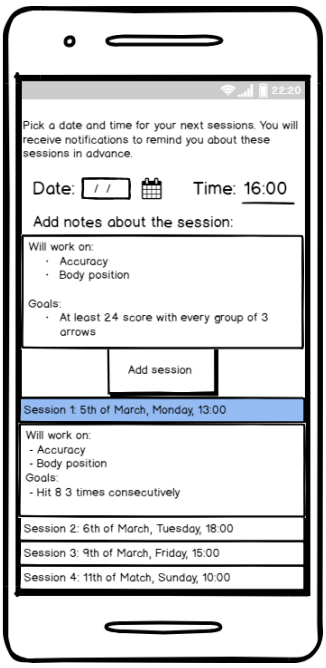
The second version of the mobile application was more complex. It had more menus than the first one and they were better defined than the first version. Everything was better thought through and it was closer to a realistic mobile application. Because we wanted to get more confident in the placement of the User Interface (UI) elements first, such as buttons and labels, this version did not include a colour scheme. The choice of colours is one of the most important aspects when it comes to applications and therefore we wanted to research the psychology behind it first. The feedback from our target audience included ideas such as adding back buttons to the menu or making it easier to navigate through the application. A concept that was inspired from this suggestion was to add a bar at the top of the application that would contain buttons that would let the user easily switch between menus. Another suggestion was to add a “Create Account” menu. Researching mobile application designs and getting inspiration from these helped us come up with better ideas that would be used in the later stages of the design. A nice example of how to design a mobile application was found on the Balsamiq support website[15].

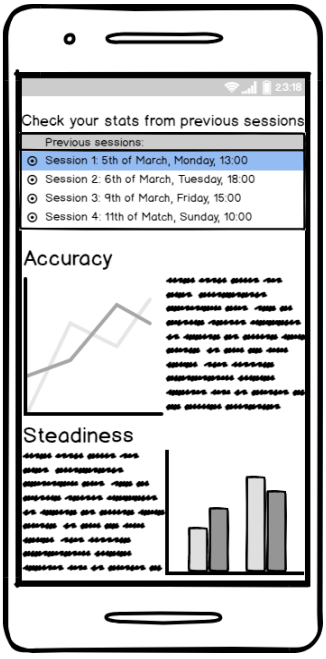
[15] "Creating a Mobile Application - Balsamiq Support Portal." https://support.balsamiq.com/tutorials/mobileapplication/. Accessed 15 Mar. 2018.

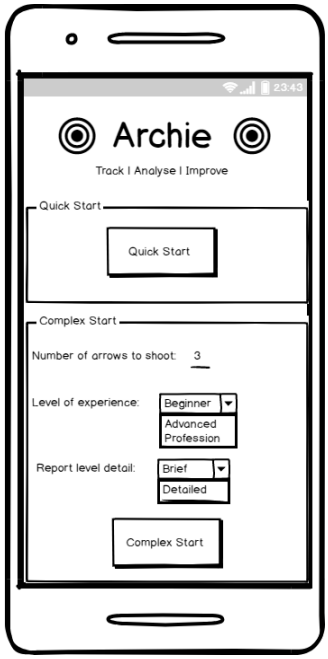

Archie
Track I Analyse I Improve
Username
Password
Log In
Start Shooting
Create account

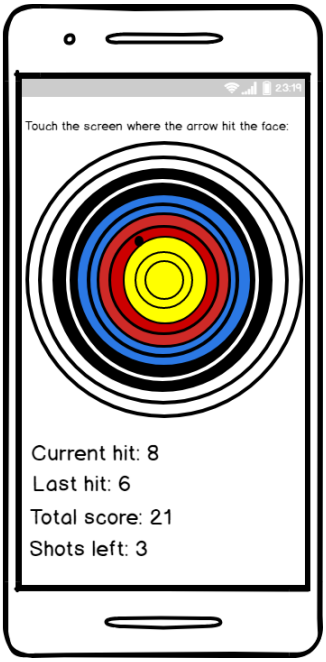

Archie
Track I Analyse I Improve
Start new session
Plan sessions
Check stats

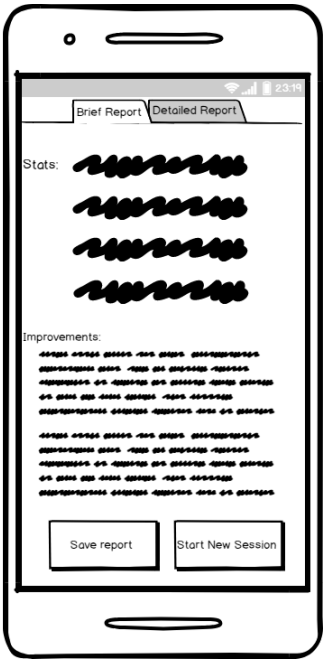

Archie
Track I Analyse I Improve
Start new session
Plan sessions
Check stats

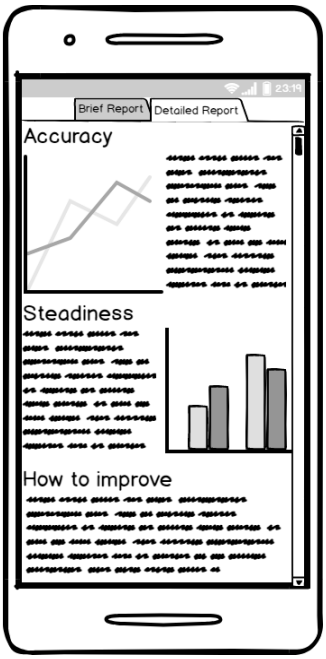

Pick a date and time for your next sessions. You will receive notifications to remind you about these sessions in advance.
Date:
Time: 16:00
Add notes about the session:
Will work on:
Accuracy
Body position
Goals:
At least 24 score with every group of 3 arrows
Add session
Session 1: 5th of March, Monday, 13:00
Will work on:
- Accuracy
- Body position
Goals:
- Hit 8 3 times consecutively
Session 2: 6th of March, Tuesday, 18:00
Session 3: 9th of March, Friday, 15:00
Session 4: 11th of Match, Sunday, 10:00


Check your stats from previous sessions
Previous sessions:
Session 1: 5th of March, Monday, 13:00
Session 2: 6th of March, Tuesday, 18:00
Session 3: 9th of March, Friday, 15:00
Session 4: 11th of Match, Sunday, 10:00
Accuracy
Steadiness


Archie
Track I Analyse I Improve
Quick Start
Quick Start
Complex Start
Number of arrows to shoot: 3
Level of experience: Beginner
Advanced
Profession
Report level detail: Brief
Detailed
Complex Start


Touch the screen where the arrow hit the face:
Current hit: 8
Last hit: 6
Total score: 21
Shots left: 3


Brief Report
Detailed Report
Stats:
Improvements:
Save report
Start New Session


Brief Report
Detailed Report
Accuracy
Steadiness
How to improve

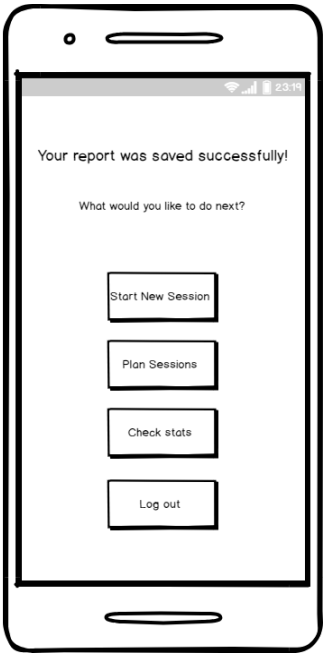
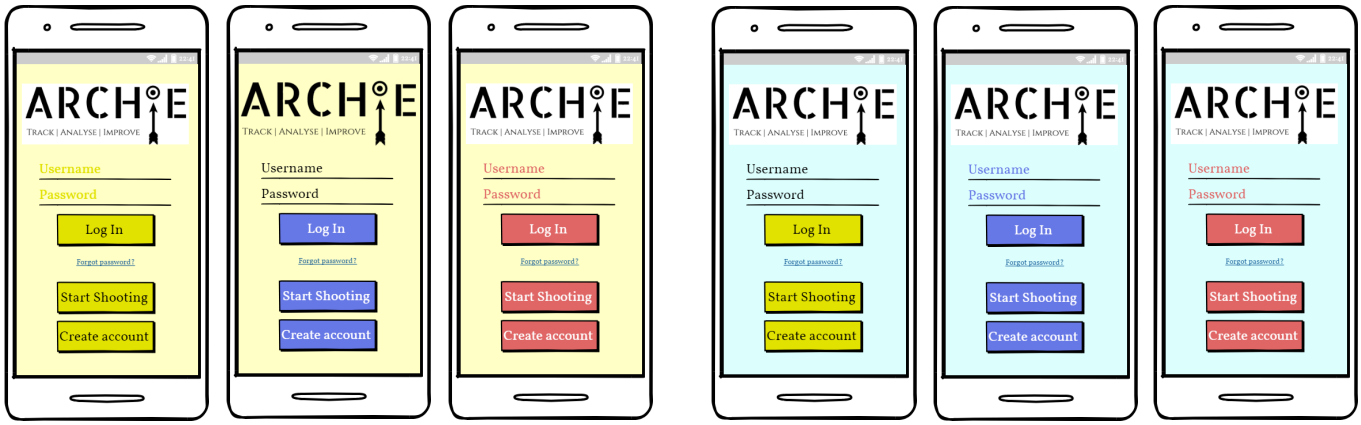
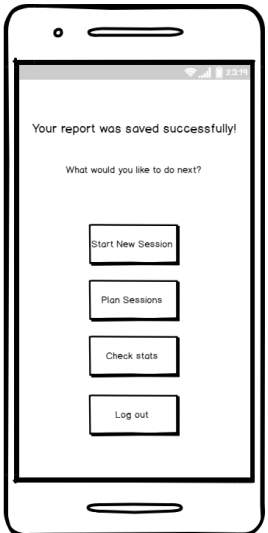

Your report was saved successfully!
What would you like to do next?
Start New Session
Plan Sessions
Check stats
Log out

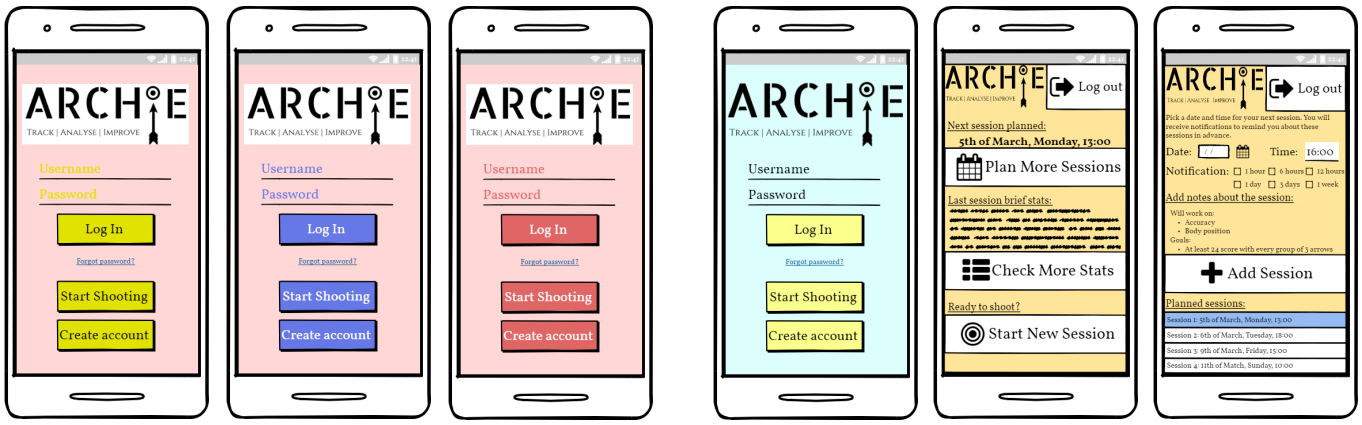
Figure 26 - Second Version Mobile Application UI

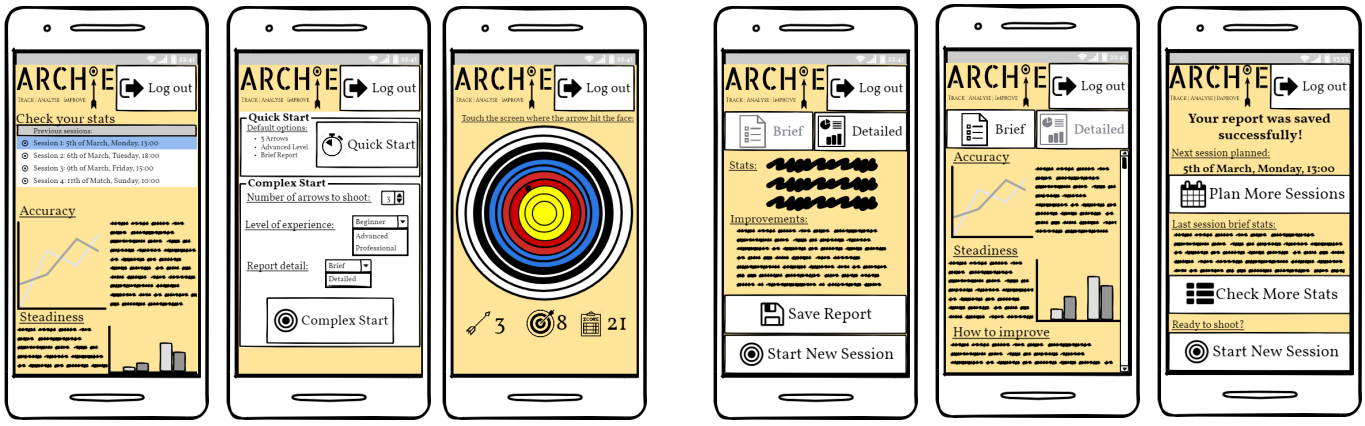
The third version of the mobile application made better use of the space available in the menu. The previous version contained a lot of empty space which was not ideal. Adding more information to the menus was essential and therefore we had to be very efficient with our space. The buttons were made bigger so they could be easier to press and more elements were added to the UI. Due to there being less changes as before, we decided to spend some time researching on the colour scheme we should use. We decided to use a combination of the colours that are found on an archery target face (white, black, red, blue, yellow). After researching on the psychology behind using colours efficiently, we found that most people prefer simple colour combinations that rely on only 2 to 3 favourite colours. People prefer simplicity over being overwhelmed by a big number of colours since it makes the content easier to understand and read. This made us experiment a bit with colours and



try different combinations.







The fourth version of the mobile application included the use of icons in order to keep the design simple but attractive to look at. After experimenting with the colour combinations we still had to decide which one is

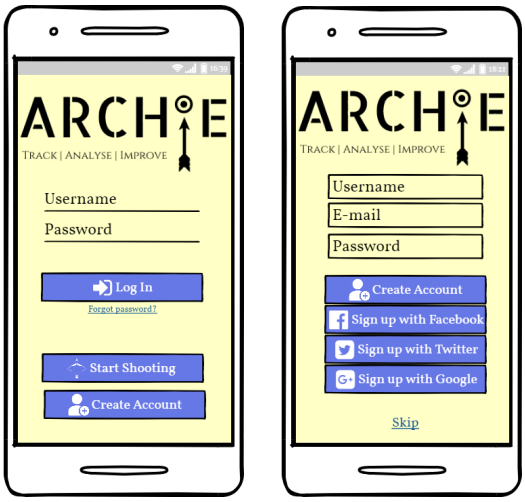
Figure 27 - Third Version Mobile Application UI

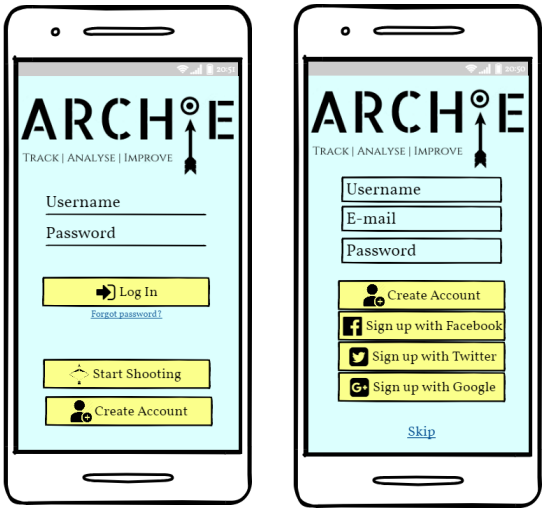
the best since two of them had a similar amount of votes from our target audience. The colour scheme that was used for this version was only a placeholder. Instead we decided to spend some time on polishing the application and making it look more professional in terms of the placement of the UI elements. The bar at the bottom allowed the users to navigate easier and be able to get to any of the big menus from anywhere. The icon and name of the menu the user is currently in was added to all the menus to allow an easier understanding of

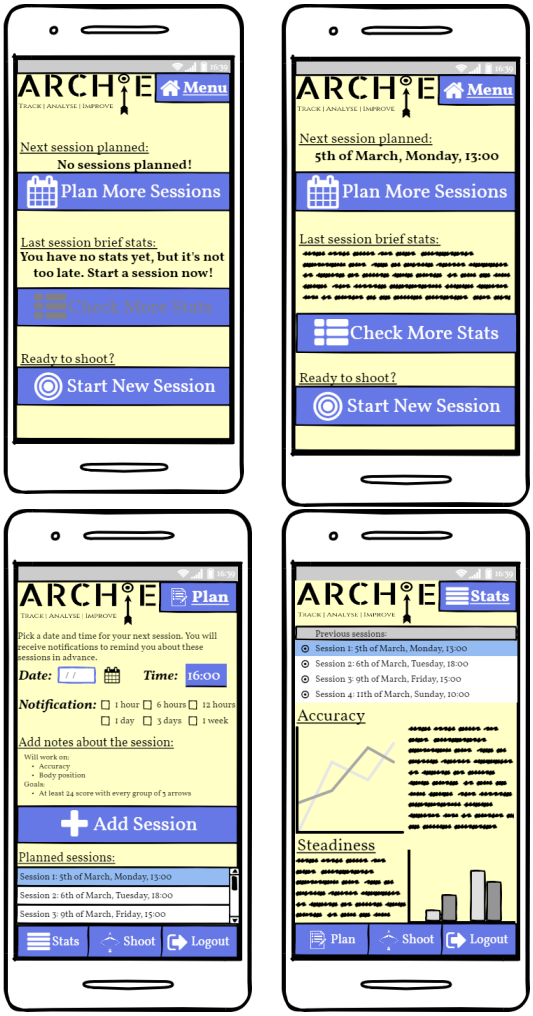
where the user is in the application.

Figure 28 - Fourth Version Mobile Application UI

The fifth version of the mobile application included each menu in both colour schemes in order to make it easier to pick between them. The layout of the menus was finalised at this point, we decided to stick to this layout for the prototype. Small tweaks were made to the shades of the colours that were used to ensure the best looking combinations. The main idea behind the fifth version was to finally decide the colours our application was going to use. A yellow background with pale blue buttons was decided in the end.







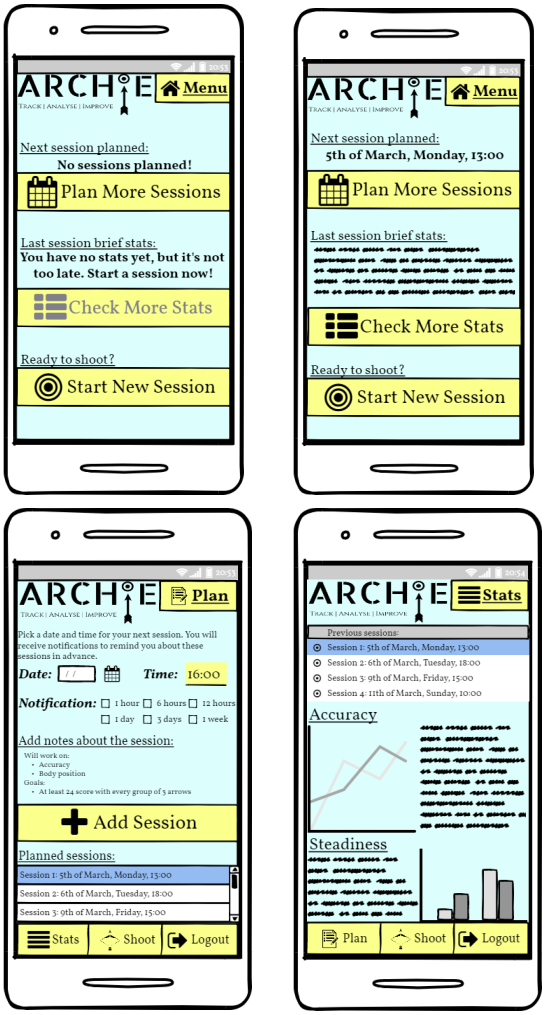
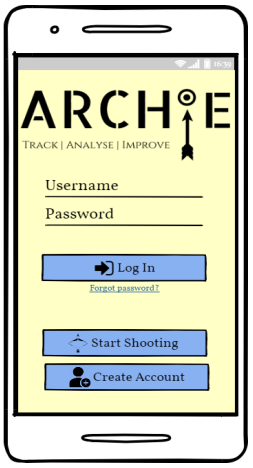


Figure 29 - Fifth Version Mobile

The main purpose of the mobile application is to help the user interact with the rest of the system. Through it, the user would be able to access and store the information obtained from the system, as well as start the sensors when they are about to start shooting. Basically, the mobile application is the interface between the user and the sensors, Arduino board and the Raspberry Pi. Since it is the part of the system that the user interacts the most with, it is required to be easy to use and attractive. It would be disastrous if the user would give up on using the system due to the mobile application being too confusing or frustrating to use, therefore its design is a core part of the success of our prototype. All the design decisions related to the application were made based on the feedback we would get from some of the archery society members through informal discussions and by allowing them to test our prototype through our physical Proof of Concept.

By going through each menu, we can explain what the user can do in each of them. This is what our mobile application would look like and the design we based our physical Proof of Concept on:



Main Menu:

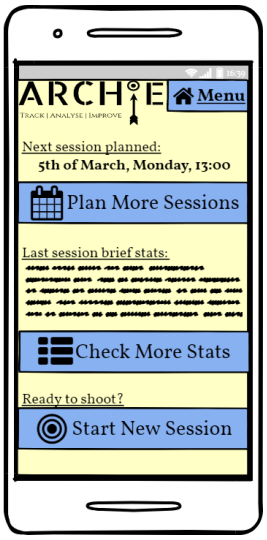
- Our logo
- The “Username” text field
- The “Password” text field
- The “Login” button that the user can press after inputting the username and password
- The “Forgot password?” button which allows the user to recover their account
- The “Start Shooting” button which switches to the “Shooting” menu
- The “Create Account” button which switches to the “Create Account” menu

Create Account Menu:

- Our logo
- The “Username” text field
- The “Email” text field
- The “Password” text field
- The “Create Account” button which creates the user’s account and adds it to the database
- The “Sign up with Facebook” button that allows the user to connect their Facebook account to our application
- The “Sign up with Twitter” button that allows the user to connect their Twitter account to our application
- The “Sign up with Google” button that allows the user to connect their Google account to our application
- The “Skip” button that allows the user to use the application without creating an account

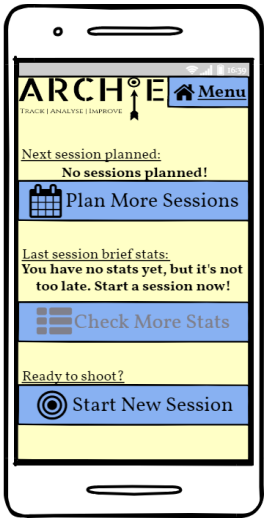
Existing Account Menu:

- Our logo
- The name and icon of the menu
- The “Next session planned” label that shows the date and time of the next session
- The “Plan More Sessions” button that switches to the “Plan” menu
- The “Last session brief stats” label that shows a list of stats from the last session
- The “Check More Stats” button that switches to the “Stats” menu
- The “Start New Session” button that switches to the “Shoot” menu



New Account Menu:

- Our logo
- The name and icon of the menu
- The “Next session planned” label that shows that no sessions are currently planned
- The “Plan More Sessions” button that switches to the “Plan” menu
- The “Last session brief stats” label that shows a list of stat
- The “Check More Stats” button that is disabled
- The “Start New Session” button that switches to the “Start Shooting” menu

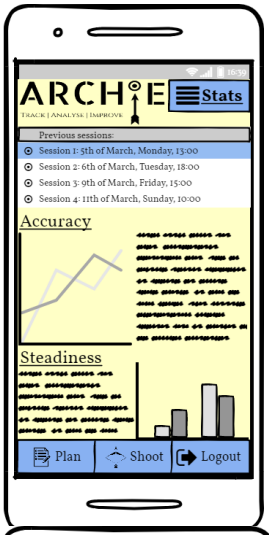


Plan Menu:

- Our logo
- The name and icon of the menu
- A date entry
- A time entry
- A list of checkboxes that allow the user to select how much time in advance they would like to receive reminders about the session
- A text box that allows the user to enter notes about the session
- The “Add Session” button that adds the session to the list of planned sessions
- The list of planned sessions
- The “Stats” button that switches to the “Stats” menu

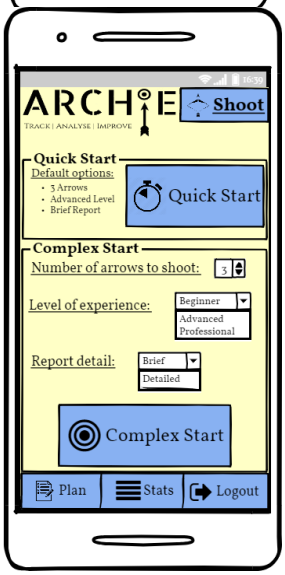
- The “Shoot” button that switches to the “Start Shooting” menu
- The “Logout” button that switches to the “Main” menu

Stats Menu:



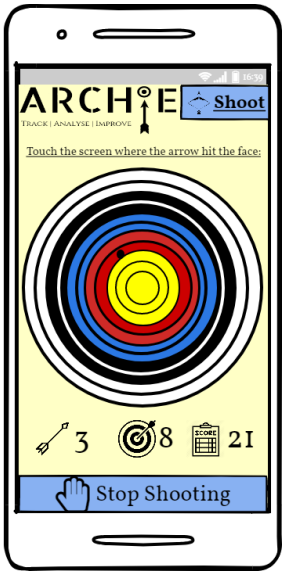
- Our logo
- The name and icon of the menu
- The list of all the previous sessions
- All the stats from the selected session in the list
- The “Plan” button that switches to the “Plan” menu
- The “Shoot” button that switches to the “Start Shooting” menu
- The “Logout” button that switches to the “Main” menu

Start Shooting Menu:



- Our logo
- The name and icon of the menu
- The “Default options” label that shows what settings would be used for the “Quick Start” shoot
- The “Quick Start” button that switches to the “Shoot” menu
- The “Number of arrows” box that allows the user to select how many arrows the intend on shooting
- The “Level of Experience” box that allows the user to select their level of experience
- The “Report detail” box that allows the user to select how detailed the report should be
- The “Complex Start” button that switches to the “Shoot” menu
- The “Plan” button that switches to the “Plan” menu
- The “Stats” button that switches to the “Stats” menu
- The “Logout” button that switches to the “Main” menu

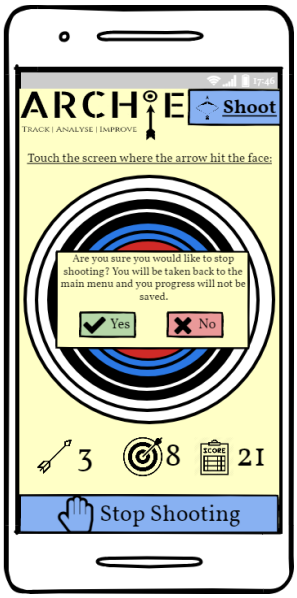
Shoot Menu (With Manual Score):



- Our logo
- The name and icon of the menu
- A target face that gets marked where the user touches it
- A label that shows how many arrows are left to shoot
- A label that shows the score of the arrow
- A label that shows the total score
- The “Stop Shooting” button that opens up a warning window

Shoot Menu (With Manual Score) Warning Window:

- Warning text
- The “Yes” button that switches to the “Existing Account”/”New Account” menu
- The “No” button that closes the warning window and allows the user to continue shooting



Shoot Menu (With Automatic Score):

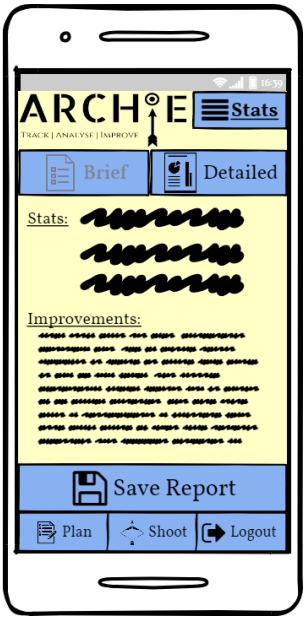
- The picture received from the camera
- A label that shows how many arrows are left to shoot
- A label that shows the score of the arrow
- A label that shows the total score
- The “Stop Shooting” button that opens up a warning window

Shoot Menu (With Automatic Score) Warning Window:

- Warning text
- The “Yes” button that switches to the “Existing Account”/”New Account” menu
- The “No” button that closes the warning window and allows the user to continue shooting

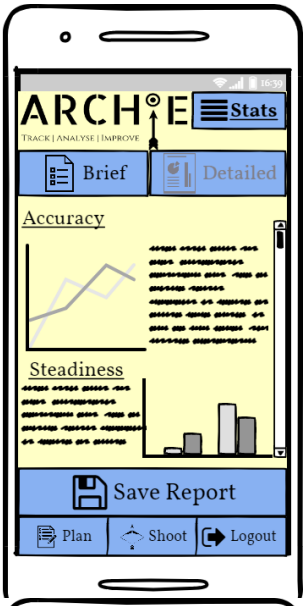
Brief Report Menu:

- Our logo
- The name and icon of the menu
- The “Brief” button that is disabled
- The “Detailed” button that switches to the “Detailed Report” menu
- A list of stats from the session
- Advice on what to improve on
- A “Save Report” button that saves the report and switches to the “End Session” menu
- The “Plan” button that switches to the “Plan” menu
- The “Shoot” button that switches to the “Shoot” menu
- The “Logout” button that switches to the “Main” menu



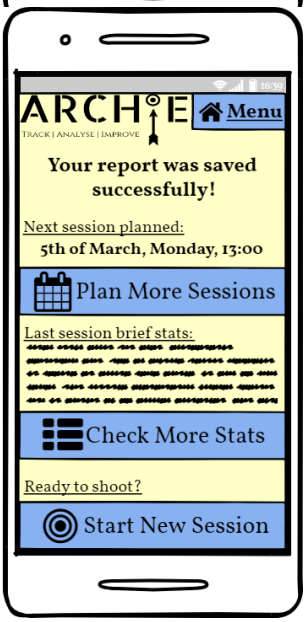
Detailed Report Menu:

- Our logo
- The name and icon of the menu
- The “Brief” button that switches to the “Detailed Report” menu
- The “Detailed” button that is disabled
- All the stats
- A “Save Report” button that saves the report and switches to the “End Session” menu
- The “Plan” button that switches to the “Plan” menu
- The “Shoot” button that switches to the “Shoot” menu
- The “Logout” button that switches to the “Main” menu



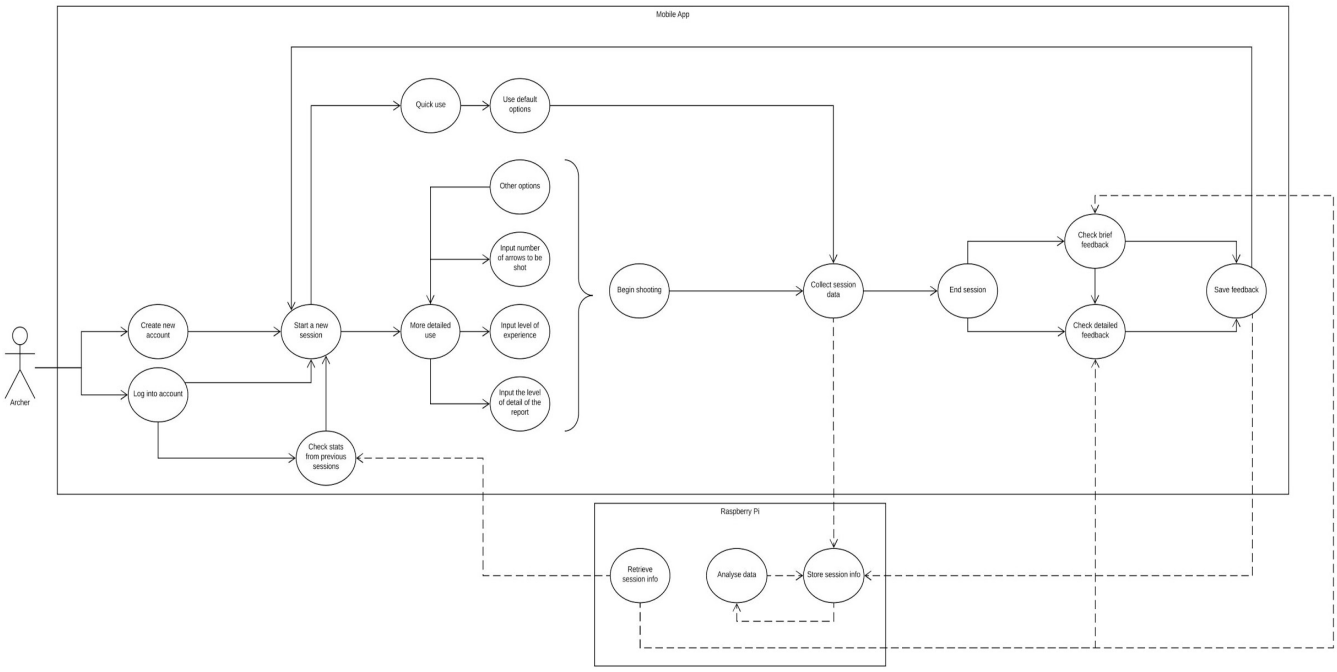
End Session Menu:

- Our logo
- The name and icon of the menu
- A label that shows the user their report was saved
- The “Next session planned” label that shows the date and time of the next session
- The “Plan More Sessions” button that switches to the “Plan” menu
- The “Last session brief stats” label that shows a list of stats from the last session
- The “Check More Stats” button that switches to the “Stats” menu



- The “Start New Session” button that switches to the “Shoot” menu

The following use case diagram shows how the user would navigate through the mobile application and how would the mobile application interact with the Raspberry Pi when storing



and requesting information:

Figure 30 - Mobile Application Use Case Diagram

In the diagram we can see that the first interaction the user has with the mobile application is to log into their account if they have one or create an account if they do not have one. The diagram was made before the design of the application was finalised and therefore the option of using it without an account is not present. The option to plan future sessions is also not present in the diagram. The advantage of having an account allows the user to see their stats from the previous sessions. If they would prefer to only read the feedback after the session and not save it then not having an account would be more convenient.

Depending on the type of user they are (old, new, without an account) they can access different parts of the system. An old user (already had an account) would be able to access their stats, they would be able to plan future sessions and they would be able to start shooting and use our system. A new user (just created their account) would be able to plan future sessions and start shooting. A user without an account would only be able to start shooting. If the user would like to check their previous stats then in this menu they would be able to select what session they would like to see the stats from and they would be displayed on the screen the same way they were displayed in the detailed report. If the user would like to plan a session then in this menu they would be able to fill in some details about the session (date, time and how long in advance they would like to be reminded about the

session through a notification) as well as see a list of other sessions they have planned. If the user would like to start shooting then in this menu they would have two ways of doing so.

The quick start allows the user to not worry about what settings they pick for their shooting session and therefore starting quicker. The complex start allows the user to customise the settings for their shooting (number of arrows, what level of experience they have and the level of detail for the feedback report) and pick the ones that are most useful to them. Once they start shooting on the screen they have information that updates in real time, such as the number of arrows left to shoot, the score of their last hit and the total score. The user has the option to stop shooting if they desire to do so. This opens a window that warns the user of the loss of their progress made so far if they decide to stop shooting. If they do not stop shooting and they reach 0 arrow left to shoot then the system will wait for 5-10 more seconds and then switches to the next screen, which is the report of their session, brief or detailed depending on their previous choices. On this menu the user can read the feedback processed and sent back from the Raspberry Pi and save the report. If they decide to save the report then they will next get sent to the end session screen that is very similar to the main menu screen.

Suggestions Algorithm

Due to time constraints, we did not implement the suggestions algorithm for the prototype as specified previously. However, we've looked back on the algorithm and it can certainly be improved. The design of the system allow us to switch out algorithms easily when new and better ones are developed, providing flexibility within the system.

This algorithm works on the assumption the sensor works perfectly and the sensor values provided are near 0 whenever returned to the original position. In the real world, we learned this is not the case, as the sensor could end up being not calibrated anymore with each movement. A system could be implemented where if the sensor was at a value for a certain amount of time, recalibrate it so the values go back to 0.

Additionally, the compared values can be derived differently instead of being hard coded. Machine Learning could be implemented so the system slowly figures out what values to use for comparison. The type of learning would be Supervised Learning. We can start with any comparison range, and as the frequency around a certain value increases, the range will slowly converge around this value, we can then tell the AI whether this range is accurate or not.

Instead of just printing out what the sensor is actually doing, the motion of the sensors should infer and provide helpful suggestions to the archer, for example, “Relax and do not hold the grip too tight”.

Poster

The poster was designed through brainstorming and market research. We looked at the links posted on canvas, which were websites informing us of different details within posters.

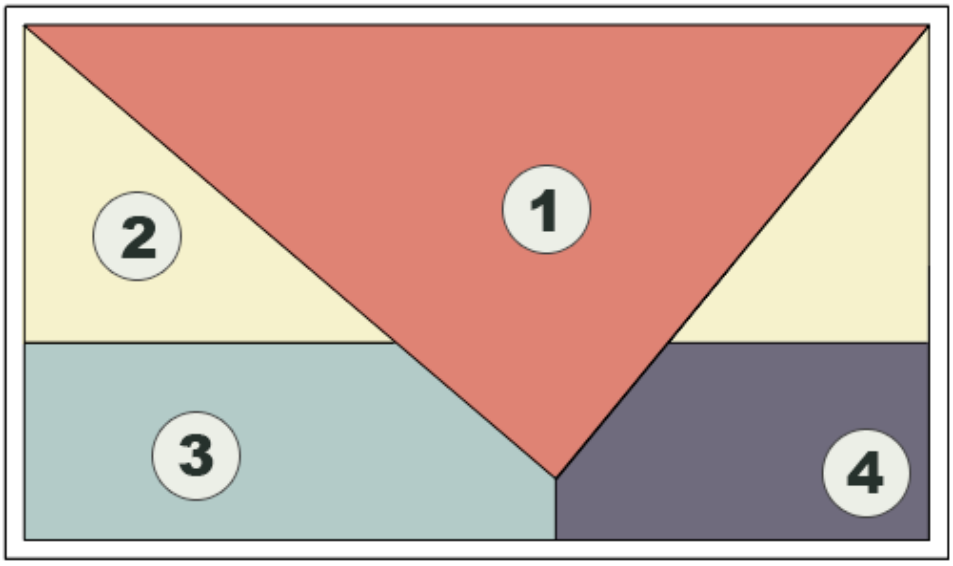


Figure 31 - Diagram showing where people typically look on a poster[16]

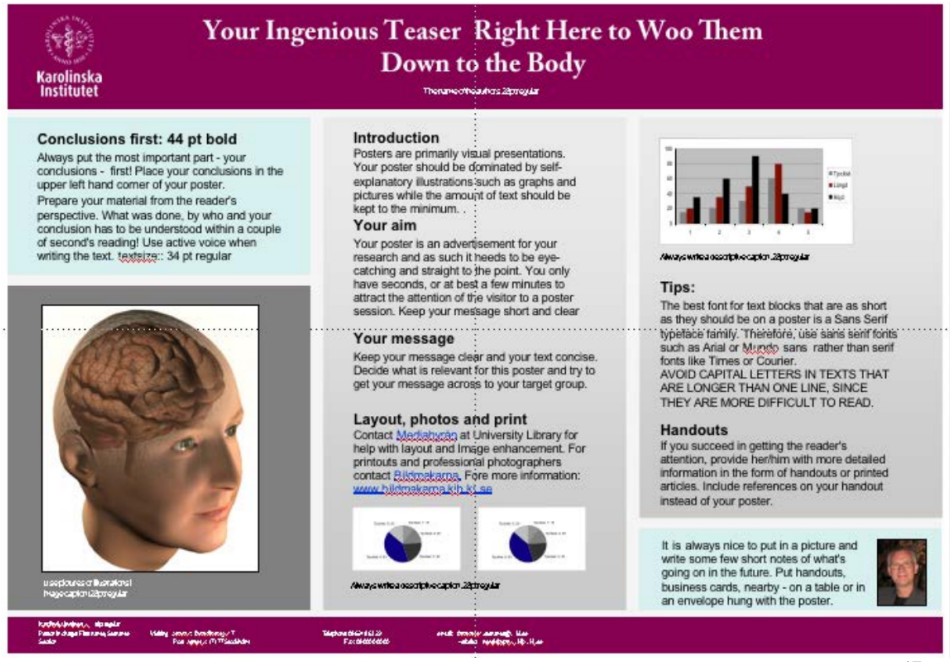
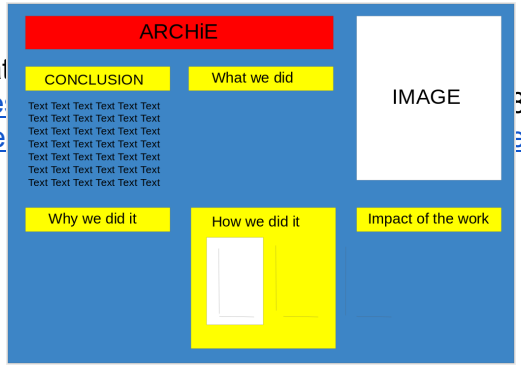


Figure 32 - Recommended Technical Poster extracted from Source[17]

We then brainstormed a number of different designs based on or around these ideas and concepts. The initial designs explored a variety of shapes and layouts, and were created using the “archery colours” of blue, red and yellow.



[16] "Academic and Professional Writing: Creat... https://writing.wisc.edu/Handbook/PosterPre... 3.
[17] "Scientific Poster Design." http://hsp.berke... ers.pdf. Accessed 05Mar. 2018.

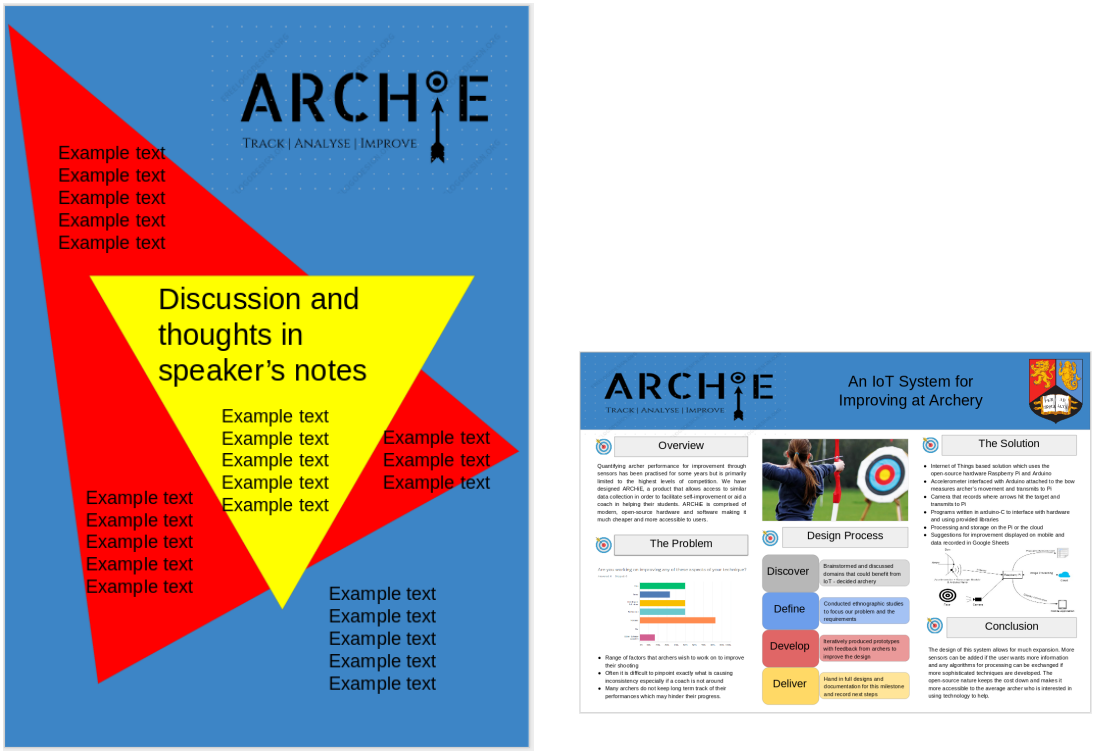


Figure 33 - Explored Poster Designs

The initial brainstormed ideas of both portrait and landscape variations were presented to the group, and we decided together the design that fit best. As this was a technical poster, we believed a landscape poster allows better presentation of information. While each of the landscape ideas had their merits, we quickly settled on the three-column idea as it was simple, effective and allowed sectioning/grouping of parts of our project.

When it came to the colours we used, it was quickly discussed that the archery colours were a good choice. Although, we were aware that these are the primary colours and we should be careful when using these. Therefore we decided to use pastel versions of these colour.

Using a three column landscape layout allowed us to find many examples to draw from, and help us with our layout and even content. The design went through several iterations. First, the poster was created in more detail now we know which design to go with, and we put mock content onto the poster so we knew what it looked like with text. With feedback from the group and more research, we repeated this process a few more times until we came up with final design that had our actual content on.

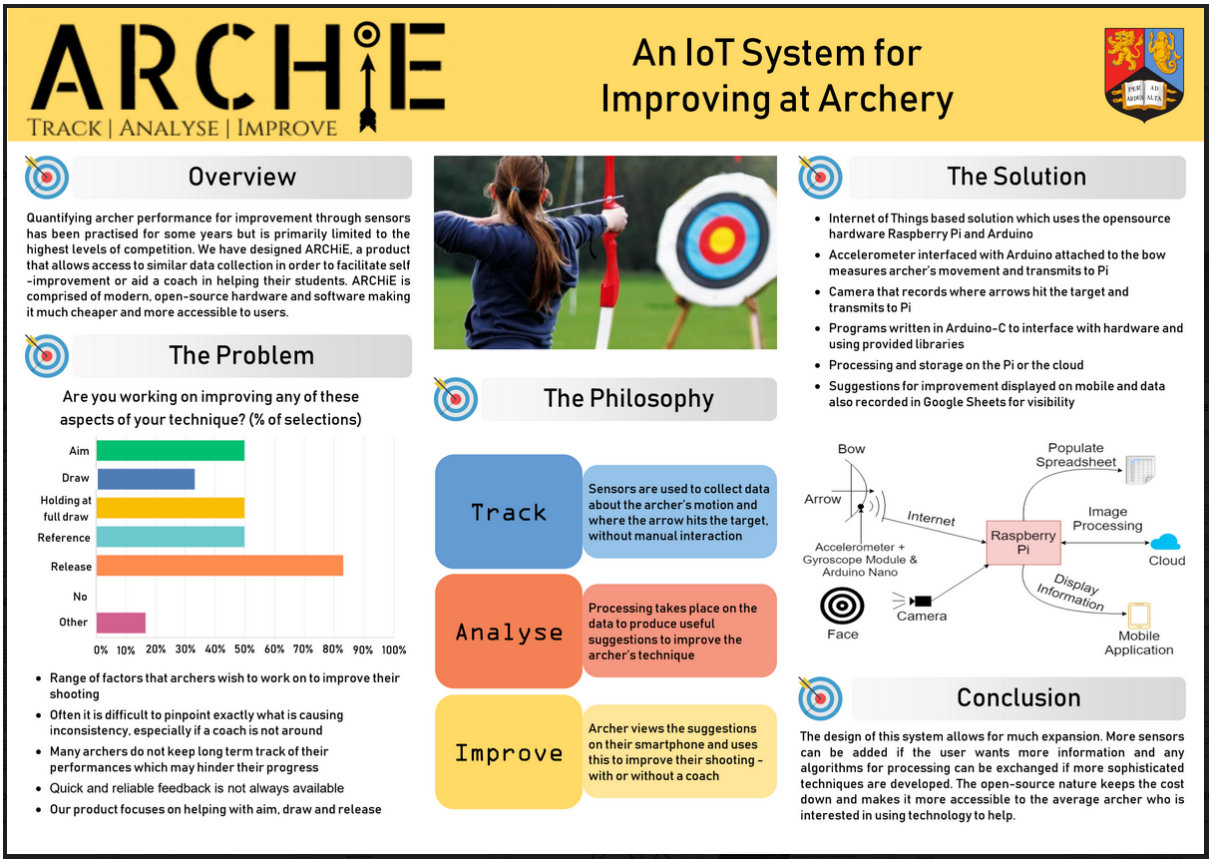


Figure 34 - Final Poster Design

Video

The video was designed through the use of market research and focus groups. At first as a group, we researched into various different types of adverts and videos about IoT devices that already existed on YouTube. From this we saw that the information delivered only outlines an overview of the functionality of the product without delving too deep into the technical details behind it. Most of the videos on YouTube were videos using human actors and slight use of CGI. We decided the use of CGI would not be feasible for us however decided that we would use ourselves as actors and record a real world video. Using our initial storyboard which we used in the Define stage, we came up with the following plan:

1. Wide shot of person lining up to shoot - Bow coming up
2. Close up of face as when they pull the string back
3. Wide shot as they release
4. Cut to shot of the target as arrow hits the target - But not accurate
5. Cut to product Logo and Tagline - Animate
6. Shot of somebody setting up the bow
    - Text: Simple and easy to use
7. Close up shot of the person sticking the accelerometer on the bow
    - Text: Uses accelerometer to track the movements of the bow
8. Side by side shots of phone application and bow to show live tracking of accelerometer
    - Text: And show live tracking of how steady you are
9. Shot of person setting up camera on the floor
    - Text: Uses a camera to track accuracy and aim
10. Shot from the perspective of the floor camera showing arrow hitting target, overlayed with how the application analyses the image
11. Switches to application screen
    - Text: Integrated with Android application to give you in depth analysis
12. Demonstration of Application Screens
    - Various texts outlining what the application can do
13. Round up with same shots as the start - But with arrow hitting the Bullseye

Using this plan we used a small focus group of students to get their feedback on what they thought of the idea. Some of the comments we received was that the structure of the video was good as it flowed in a very logical sense however they also commented that there was a lack of humour which meant it sounds very boring and not very memorable.

Also after this we watched the example videos from last years projects and realised that we preferred the animated/drawn videos compared to the real world recordings. We found the animated videos more engaging as well as being more light hearted making it easier to watch. Another thing that we noticed is that the music had a very big impact on the overall video and so we decided to have very upbeat music as this would be more invigorating and keep the audience engaged for longer.

So from all these we storyboarded a new idea which followed the structure from the initial idea but would focus on an animated stick figure. We also decided to emphasise our brand

tagline further by using the three words Track, Analyse and Improve to differentiate the three segments of our video.

We then used an iOS application called Animatic to draw out the animation and create the video content and then layered music, sound effects and text using Final Cut Pro X.

Conclusion

Overall, we believe our product would be commercially viable given the appropriate time and funding. Our designs have gone through multiple changes following an agile approach. Having a physical prototype to test would have allowed us to confirm or falsify our aspects of our design. We believe the project can be expanded easily in different aspects. We would start by creating a physical prototype as detailed in this report. Usability testing would be valued, and achieved through tests with the archery society. After some testing, a high quality prototype should be created, which could be commercially sold. A mobile application should be developed, as one thing we found was that a lot of this project could be done with a mobile phone. The mobile application should be the centre point of the product, along with any external hardware necessary. Other areas for expansion could be the camera for automatic shot tracking, either through a camera that comes as part of the kit or integrating into the mobile application to allow a photo to be taken and processed. A strain gauge similar to the Sweet Spot can also be looked into, to develop as either a separate product, or preferably integrated with the rest of ARCHiE.