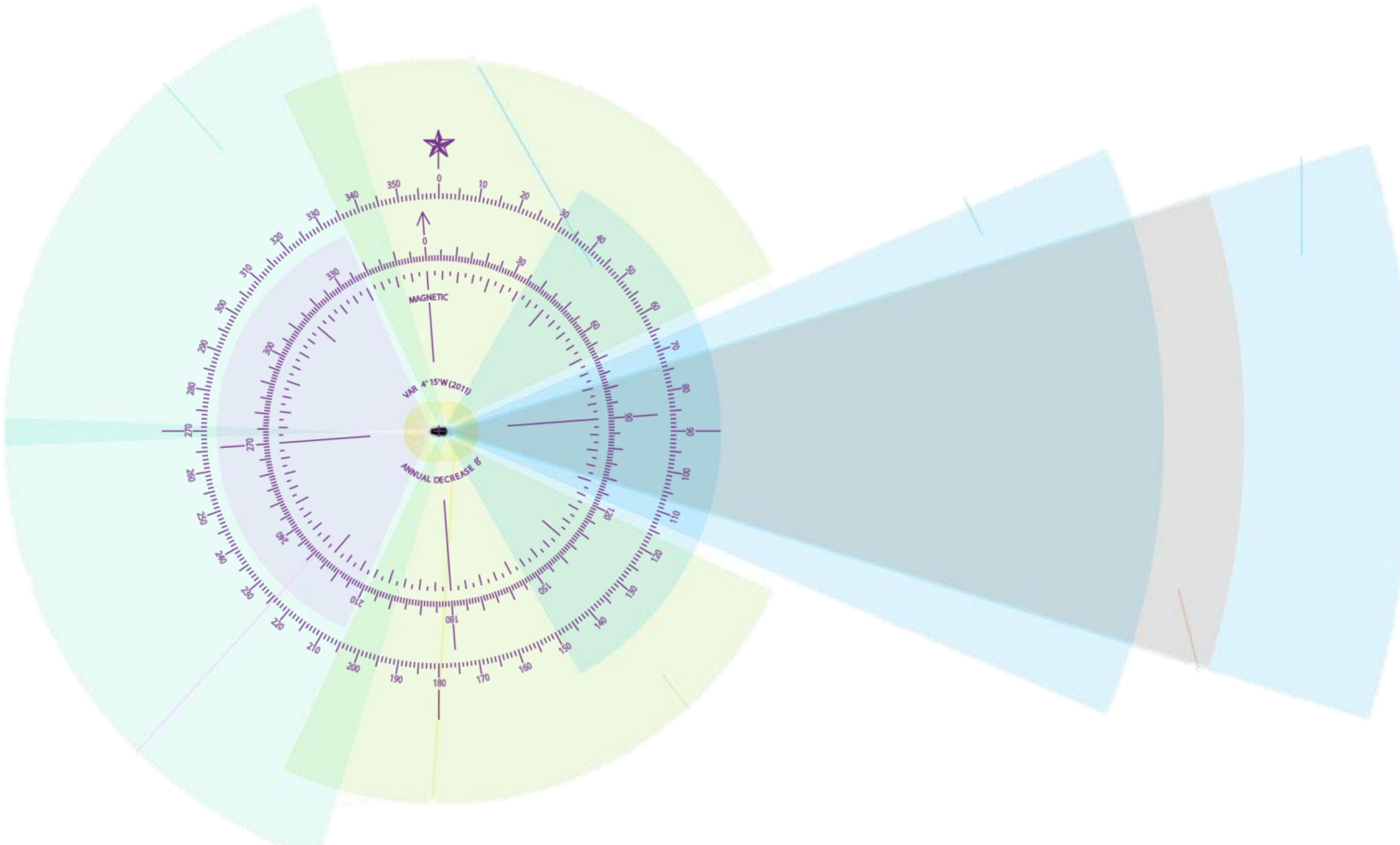

EE2 Group Project

NAVIGATIONAL AID FOR THE VISUALLY IMPAIRED

Group 8 | Electrical and Electronic Engineering | 13 December 2018

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Summary of Proposal

The selected problem proposal for the project is "Navigational Aid for the Visually Impaired in Public Transport Areas". There are an estimated 285 million people which are visually impaired worldwide [1]. In the UK, there are 350,000 people registered as blind or partially sighted in 2014 [2]. It is estimated that by 2050, the number of people with sight loss and blindness in the UK will rise to 4 million [3]. They often face discrimination and their difficulties are not listed as one of the problems to solve in the "Millennium Development Goals", this excludes them from many development initiatives and funding systems. One of the vital problems the visually impaired face daily is navigation, specifically when using public transport. Members of the Youth Forum of the Royal London Society for Blind People (RLSB) stated that they want to navigate London's underground tube system independently [4]. The predicament they must face is the inability to read signs and gain information for the transportation they wish to use. For example, finding the right stop, getting on the right bus and getting off at their desired destination can prove to be very difficult. A research reveals that 70% of visually impaired people have missed their bus stop at some point. [5] Assistive systems or services provided in public transport areas are limited. For instance, the absence of a readable timetable formatted for the blind and the lack of acoustic information about arriving vehicles [6]. A survey done by the Royal National Institute for the Blind found that of 800 blind and partially sighted people, 40% relied on others to drive them. [7] Therefore, a solution which allows them to navigate public transport areas independently, would not only deliver more freedom for the visually impaired but also increase efficiency for the society.

Hence, the objective is to develop an assistive technology that would aid visually impaired people with navigation, focusing on public transportation areas. This includes indoor areas such as airports, train stations, underground tube stations, and outdoor areas like the bus stops. The general requirements for the solution are the following:

- Can guide the user from starting point to their desired end point
- Can inform the user of their current location
- Can provide the user with information regarding the public transport schedule
- Is autonomous, lightweight and small which makes it ideal for travelling and moving

Design Criteria

1. Performance

The product is an Electronic Orientation Aid (EOA) providing a visual substitution for the visually impaired. It will be specialized for navigation in public transport related areas. The product will have the following functions:

• Guide the user by informing the proper route to take when navigating public transport and direct the user to their desired point of destination
• Provide feedback and clear notification that can be interpreted by a blind person (i.e. auditory, vibration)
• The product needs to provide fast processing for the exchange of information between the sensor and the user
Provides the user with information regarding the public transport timetable/schedule
• Operational for up to 5 – 7 hours a day without the need to charge

2. Environment

The most significant environmental operating conditions to consider are:

• Crowded areas: most public transport areas will be crowded, especially during peak hours. The product's sensors must still be able to intake information and perform its function.
• High noise level: one method of feedback considered is by auditory notification, the product's auditory feedback needs to be heard by the user.
• Temperature range: -15C to +50C so that the device can operate outdoors.
• Indoor/Outdoor Environment: should be robust and be able to withstand shocks and dirt
• Water resistant level of at least 3 ATM (Splash/Rain resistant)

3. Customer

The target customer for the product will be visually impaired individuals. Specifically, the main target will be for visually impaired people who travel or commute often. The most active from the demographic of visually impaired individuals will be those that are young and in the working class. Therefore, the age for our target customer will range around 18 – 45 years old. However, the product will not be limited to the specified age ranged.

4. Standards and specifications

Considering the product's users are visually impaired people, the product must have high standards to ensure safety and reliability. To maintain these high standards, certain specifications must be met. The specifications for an EOA are given below:
• Defining the route to select the best path;
• Tracing the path to approximately calculate the location of the user;
• Providing mobility instructions and path signs to guide the user and develop her/his brain about the environment.

5. Quality and Reliability

The product must have a great quality and reliability for our target users. Any false notices or malfunctions could have serious repercussions on the users or inflict unwanted injuries. Hence, the product must undergo a reliability test once finalized. The "mean time between failure" and "mean time between repair" values should be in the 10,000 hours range. It is a low estimate as we do not require our product to be continuously in use as its aim is to be used only within public transport areas.

6. Testing

The manufacturing of the product will go through different stages of development. Testing our product at each stage of development is necessary to ensure that we keep track of our development process and our product is error-free. Testing will be done after installation of each stage / combining the modules together to ensure that the modules work when connected. The finalized product will be tested as well to see it is fully functional.

7. Legal

According to the Consumer Protection Act, manufacturers, distributors, suppliers and retailers could be held responsible for damage, injury or death caused by their product or any of that product's component parts. For our product, the worst-case scenario will be that a failure might cause a serious injury. The legal consequence would be the user suing us for liability. Therefore, our final product would need to go through a variety of different legal registrations to be on the market.

8. Safety

This product prioritizes the safety of its user. Safety considerations include the prevention of the electrical circuitry of the product, from coming in contact with water, as it may cause electrocution. Our product must also include safety measures should it fail. It should have a way to contact emergency/assistive services. As the product only aims to aid the user in navigating, it should be used in conjunction with traditional assistive devices; e.g. white cane.

9. Target product cost

The project budget is £200; thus, it is important the cost of the product stays within or ideally below it. The cost of the microcontroller is around £25, this will act as the minimum/base cost of the product. Other component costs will be determined once the exact solution is chosen. It is estimated that independent of the solution chosen the product should not cost more than £125. Specific target product cost for each solution is discussed in the High-Level Design Section.

High Level Designs

The following high-level designs were devised for the solution to the proposal. Each of the high-level design varies from each other and focuses on a specific mode or area of public transport.

HIGH LEVEL DESIGN 1

Navigation in London's Underground tubes poses a challenge for visually impaired people. Without the ability to read directions or signs, it may be difficult to find the way out or choosing the correct line/platform. The solution aims to provide aid in reading the directions/signs and navigate them accordingly.

The solution can be implemented as a device that will identify signs (e.g. tube platform "way out" signs or tube lines like "Victoria Line"). It is connected to the user mobile phone via Bluetooth. The user may choose a destination and the application will provide audio navigational instruction.

Technical Design

The mobile application will be developed for android users, using JAVA as a computer language and Android Studio. It should give the right instructions to the user based on the information that the image processor module would have produced. The user interface for the application should include speech recognition, access to the microphone. The feedback to the user will be in the form of audio instruction.

The sensing aspect of the solution is by the camera which is connected to a Raspberry Pi. Coding the Raspberry pi will be done in Python using Visual Studio. The camera will read the signs by image processing. The video is then processed by the microcontroller in order to recognize the different signs by scanning and matching them to an element of sign database. This can be done using OpenCv library.

To interpret the signs, the AI neural network requires a large database that is composed of images of the signs from a variety of angles and of different contrast. The database should undergo processing and testing beforehand such as Gray Scaling and Image Normalization [8].

The hard shell of the device that encapsulates the circuitry will be made by laser-cutting, using acrylic sheets. The device should be able to be clipped on to the user.

Estimated Cost

Name of the component	**Cost (£)**
OV5647 Camera Board /w CS mount Lens for Raspberry Pi 3 / B / B+ / 2 Model B [9]	24.14
Raspberry Pi 3 Model B+ [10]	34.07
Acrylic Laser Cuttings Sheets	6
Total	64.21

Feasibility

In the case of product failure and the it provides unclear navigational directions, there is a safety feature present in the underground station that prevents the user from walking into the tube tracks, the tactile pavement indicating where the edge is.

Developing the solution will require knowledge on Computer Vision and skills in Machine learning (AI neural network), Image processing using OpenCv, Python and JAVA. These skills can be acquired over the Christmas break and during the implementation & development process of the project. A team member with experience in mobile development and programming in JAVA will lead the group when developing the application. The course to learn the skills can be found through various resources and expertise such as the Data Science/Machine Learning Society, which provides tutorials to advanced machine learning techniques.

With 4 months remaining before a prototype must be constructed there is a time constraint to overcome. The team would be divided into 3 sub teams: the first team to work on image processing, the second on the interface, and the last team to work on the main architecture of the application and integration.

HIGH LEVEL DESIGN 2

Bus stops in London provide bus schedule to passengers – which bus is coming to the stop and in how much time – via a LED screen and board. However, since the information is conveyed using a visual medium, visually impaired people often find it difficult to determine when the bus is arriving. Therefore, we propose to develop a device that detects bus stops within close proximity to the user and provides all relevant information (e.g. name of the bus stops and its schedule)

Technical Design

In order to produce the device, we will require several technical skills regarding implantation of the following modules for the device – the GPS tracking module and the input/output module. The GPS tracking system contains a microcontroller unit (MCU), a global system for mobile communication(GSM) module and a global positioning module(GPS)[11], and the input/output module contains a 3.5mm headphone jack socket and a button[12].

The MCU module will be in charge of taking the input data - a digital form of the coordinates of the device - from the GPS module, and processing it[13]. The GSM module is needed to make wireless connection to the server for fetching the bus timetable for each stop[14]. The GPS module will detect the coordinate of the device. For the input/output module, the 3.5mm socket will output an analogue signal, which can be used to relay the information by audio. The input relies on a button, which the user presses which will inform the user of the bus stop name and then its associated timetable.

When the user presses the button on the device, the device first checks whether there is a bus stop within a certain radius. If there isn't any bus stop near the device, the MCU gives an acoustic output that there is no bus stop nearby. If there's a bus stop within the radius of the device, the MCU will then proceed to identify the bus stop name and timetable. The device will fetch the bus timetable from the server for that specific time interval, which will be about 30 minutes from the time when the device was called, and by using text-to-speech, it will read out the bus timetable to the user.

Estimated cost

Name of the component	Cost (£)
ATMEGA328-AU - 8 Bit MCU, Low Power High Performance, AVR ATmega Family ATmega328 Series Microcontrollers, 20 MHz	1.69
MIKROE-1375 -Daughter Board, GSM2 Click, GSM/GPRS 850/900/1800/1900MHz Quad-Band Frequency, SMA Connector	39.95
GPS Receiver Module, SiRFstarIV, ROM Based, Mini Outline - A2200A	15.56
3.5mm Jack Socket, 3 Pole, Black, 2 Pack - PSG08282	1.44
FL13NR - Pushbutton Switch, IP67, Momentary Spring Return, SPST-NO, Quick Connect	6.56
Total	65.2

Feasibility

It needs to be ensured that the circuit for the device is encapsulated properly and the final device is small and lightweight to make it user friendly. The code to program the microcontroller will be written in Python or Java. Integrating the hardware and software together will be the most challenging part, hence many tests will be conducted to ensure the successful integration. Knowledge on setting up a GPS tracking system and producing text-to-speech output via 3.5mm jack will be heavily researched over the Christmas break to ensure that we can begin constructing the prototype by the start of next term.

The estimated cost for the development of the device is £65.2, which is within the budget. Since the device is in its design stage, the estimated cost could be reduced if cheaper and better-quality alternative components are used instead. The calculation is since it will be purchased individually and not in bulk, the price will be higher compared to if purchases in bulk was made; which can reduce the cost up to £60.6.

Another challenge will be acquiring the bus timetable information. The data the device must fetch will be from a third-party source belonging to the TFL database. Before developing the actual product, we must acquire their permission to access the database.

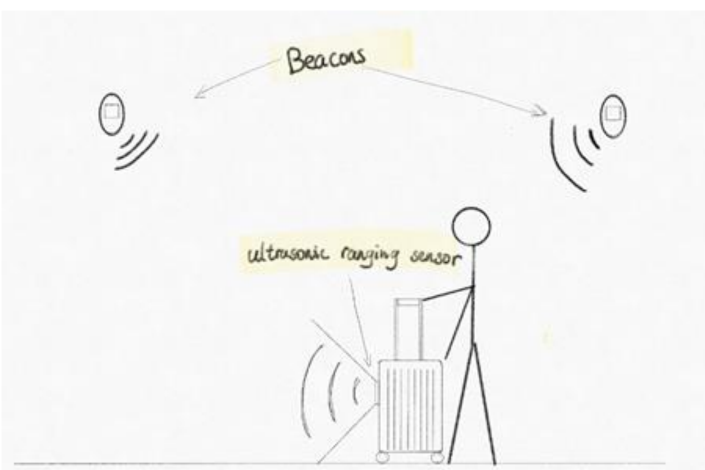
HIGH LEVEL DESIGN 3

Heathrow airport is the second busiest airport in the world, it served 78.0 million passengers in 2017. [15] On average, Heathrow handles about 220,000 passengers per day. With such a busy scene and complex layout of the airport, it can be a challenge for the visually impaired to navigate to their gate. Assistance is provided by airport by booking 'meet and assist' service in advance or going to special assistance area; but this requires user to first navigate to the special assistance area. The solution is a navigational suitcase which helps visually impaired people navigate the airport and avoid obstacles. The suitcase is equivalent to an electronic guide dog. It interfaces with signals from beacons which are to be distributed across the airport.

Technical Design

Indoor positioning can be achieved by using BLE beacons. Distance between the beacon and the receiver can be estimated based on the ratio of the beacon signal strength (RSSI) over the calibrated transmitter power which is a known signal strength in RRSI 1 meter away. [16] Furthermore, the estimation accuracy can be improved by trilateration of the beacons. We opted for the BLE beacons as it provides a more accurate indoor location-information compared to the GPS. It also have a battery life of approximately 5 years[17]. The BLE reader will be the user's smartphone. A mobile application needs to be developed to receive and process information from the beacons as well as sending instructions to the microcontroller through the WIFI. The app should also allow the user to input their destination.

Ultrasonic ranging sensor will be used to detect obstacles in front of the user. The ultrasonic sensor will be connected to the Microcontroller (Arduino) which will process the input from the sensor and outputs the command to the wheels. Electrical motors will drive the wheels of the suitcase and are controlled by the Microcontroller. The concept of the suitcase is similar to that of an autonomous vehicle. When it detects an obstacle, if it is moving (such as a person) it will simply stop moving and wait for the obstacle to pass. If the obstacle is stationary it will drive and guide the user around it.



Estimated Cost

Name of the component	**Cost (£)**
Arduino Uno	19.97
2x RS PRO DC Motor, 19.68 W, 3 → 7.2 V dc, 375 gcm, 19000 rpm, 2.3mm Shaft Diameter	10.92
3x TruSens HC-SR504 Ultrasonic Ranging Module	7.56
3x BLE beacons	60
12V Battery pack	4
SLAZENGER Black 47cm Trolley Suitcase	5
Powersonic PS-1270 12V 7.0Ah SLA battery	16.01
Total	123.46

Feasibility

One of the problems is the legality of our product, incidents may occur due to the sensor malfunctioning. For instance, a collision between the user and the obstacle may occur if the ultrasonic ranging sensor fails to detect the obstacle and guide the user away from it. Therefore, the user may still need to use a traditional white can as a precaution. This prevents the user from freely using both their hands, which makes the solution infeasible to a certain extent. The speed of the suitcase will be kept at around 4 km/h, so even when colliding with an obstacle it will have a minimal impact and prevent any serious injuries.

Another limitation to the product will be that it the product cannot be checked in, since the product needs to be with the user at all times, the suitcase can only be used as a hand carry luggage.

The cost of the product will not be borne fully by the user. The implementation of the beacons relies on the airport. Hence, the product cost for the Visually impaired user will be £63.46.

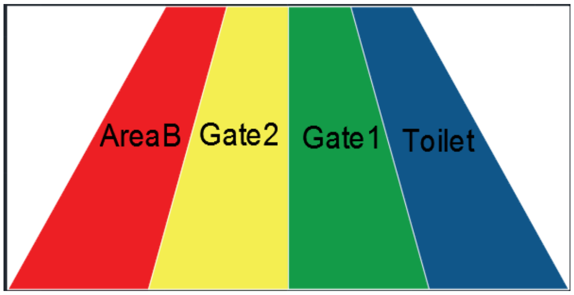
HIGH LEVEL DESIGN 4

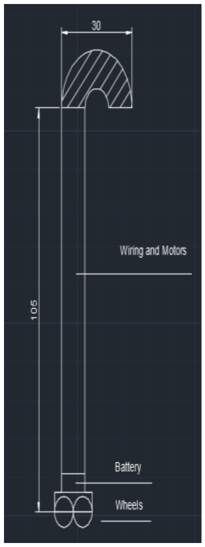
Navigation is important for visually impaired people when they need to access different places; traditional assistance such as guide dogs and canes are still being used. Nowadays there are various technical devices to help visually impaired people navigate. However, there is none that is fully developed and widely used in indoor places, specifically airports. Although Heathrow provides lots of assistance for people with disabilities, traditional help are still being deployed such as providing specially trained assistance dog and wheelchairs. [1] Especially for visually impaired people, there has not been any cutting-edge technology that allows them to access the airport freely and independently. Despite Heathrow recent partnership with the new app called 'Aira' for blind people, where trained professional agents are hired for advice on navigating through the airport and help on finding specific locations. [2] With our design, no extra workers are hired and allows user to be more independent.

The design for the solution consists of coloured tapes placed on the floor, a smart cane with a wheel attached driven by the motor and a photoelectric sensor. The cane with a photo-electric sensor for colour detection will guide the user to their desired destination, by analyzing the information received from the colour tape. With this cane, visually impaired people can easily access different places at the airport without better ease.

Technical Design

The major electrical components for inside the smart cane with be the photo-electric sensor and a microcontroller (Arduino or Raspberry Pi). When the photo-electric sensor is in use, the microcontroller will be receiving any data the sensor detects, then it will be decoded and analysed before sending signals to the motors and wheel. For the User Interface, a mobile app (Android/IOS platform) is needed for the user to locate the destination by voice, the information is sent to the microcontroller wirelessly. Besides the communication part, the design of the colour tape will have an important role as well. Different combination of tape and colour will be used to identify the routes for the different locations, labelling on the colour tape allows the user to go through these labelled 'check point' to obtain their current location.





Estimated Cost

Name of the component	**Cost(£)**
ATMEGA328P-AU - 8 Bit MCU, AVR ATmega Family ATmega328 Series Microcontrollers, 20 MHz, 32 KB, 2 KB, 32 Pins, TQFP	1.55
Sick, M18 x 1, PNP-NO Inductive Sensor 69mm Length, 10 → 30 V dc supply voltage , IP67 Rating	26.60
70cm (28 inch) Ambutech symbol cane	12.60
100mm Cushion Rubber Tyred Wheel with Steel Centre (Require x 2)	5.14
Total	54.99

Feasibility

Analysis of Circuit form EE1 is needed to design circuits with filter and Op Amp. High level programming skills in Python, C++ and Java are needed to design the mobile app (UI) and program the microcontroller. For the design of the tape, expertise level in mathematics are needed in order to build a model which consists of the sequence in different combination and colour corresponding with the location and destination.

The product is not economically feasible. The implementation of directional tape in the airport's floor infrastructure may be costly, even though cheap coloured tape is used, since it is a large area. Hiring extra assistance service to help people with disability even be more cost effective to the airport. The airport will also need to maintain the color in the long term, ensuring it does not become faded.

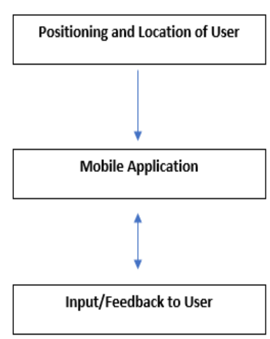
The deployment of the project is environmental-friendly, no bad effects will be made to the environment as everything can be recycled and reused.

High Level Design 5

Navigating independently in an airport terminal can be a challenge, especially for the visually impaired. Although London's Heathrow Airport provides disability services for the visually impaired, they are limited and there is room for improvement with modern technology [22]. The developed high-level design solution to help the visually impaired navigate the airport consists of the use of BLE beacons, a mobile application and a haptic belt.

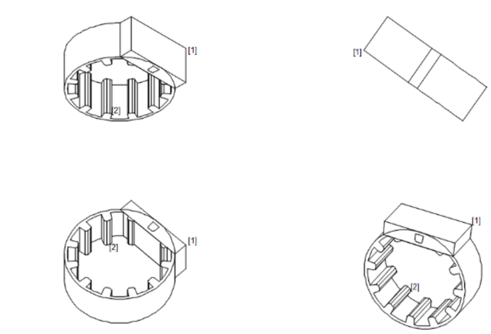
Technical Design

The solution consists of three stages, as shown in Graph Flow.



The positioning and location of the user will be determined by the use of BLE (Bluetooth Low Energy) Beacons. The beacons will be placed throughout the terminal and based on the transmitter-receiver principle, the BLE beacons will emit signal every set interval and the reader will detect the signal. Smartphones are capable of reading BLE signals (acting as BLE readers). Due to their low transmission power BLE signals are not easily influenced by their surroundings. They also have a range of 10 - 70 meters. [23] Trilateration can be used to calculate where the user is relative to the beacons and hence identify their position in the terminal.

An application for android will be written in Java using Android Studio IDE or Eclipse to process the transmitted information given by the beacons. Key feature of the application will be the user interface. The application will require speech recognition and access to the user's microphone. It needs to have the airport terminals map and needs to be connected to the wifi in order to be



[1] : Belt lock with battery and circuit inside
[2] : Vibrator

updated on any information regarding flight delays. The application will control the feedback system. To ensure maximum safety the application would have a contingency should it fail to provide direction. It will call Airport Services to alert them the user needs help.

The feedback to the user is given by a haptic belt and audio. The haptic belt works by causing vibrations in specific parts of the belt that correspond to a direction. For instance, vibration on the front corresponds to a forward direction. This improves the quality of the solution as it allows for 360-degree orientation of the user, which may otherwise be limited if only done by audio instruction. The audio instruction will give information regarding the user's placement in the terminal, such as which gate they are in or what floor. The haptic belt can be constructed using vibration motors, accelerometer, magnetometer, an Arduino Uno, a belt and basic electrical components (Resistors, capacitors, etc..). It will be connected to the app by Bluetooth.

Feasibility

In terms of feasibility, the haptic belt is mostly hardware and can easily be done due to previous experience with the EE Rover Project. The challenge may come from the software aspect of the design and the calculations for the positioning of the user. To overcome this challenge, group members with programming background will learn Java and how to develop an app over the duration of the Christmas break. Several challenges may arise when using trilateration which will reduce accuracy of determining the user's location. Such as dynamic object obstruction and multipath effect. Indoor Position System (IPS) can be used if needed; it incorporates the use of BLE beacon and other sensors in the user's mobile device.

The use of RFID tags were considered since they are cost effective, however the readers for RFID tend to be more expensive. With BLE beacons almost all smartphone in the market can act as a reader.

The solution requires the airport to have beacons placed throughout the terminals. This may be economically infeasible. The partial cost of this solution will be borne by the airport, as it requires them to install the beacons. Increasing trends in the use of beacons and Iot may mean that airports will adapt to using beacons in the near future. There is precedence with an American Airline, the Dallas/Fort Worth international airport, that had a 6 month testing period implementing beacons. [24]

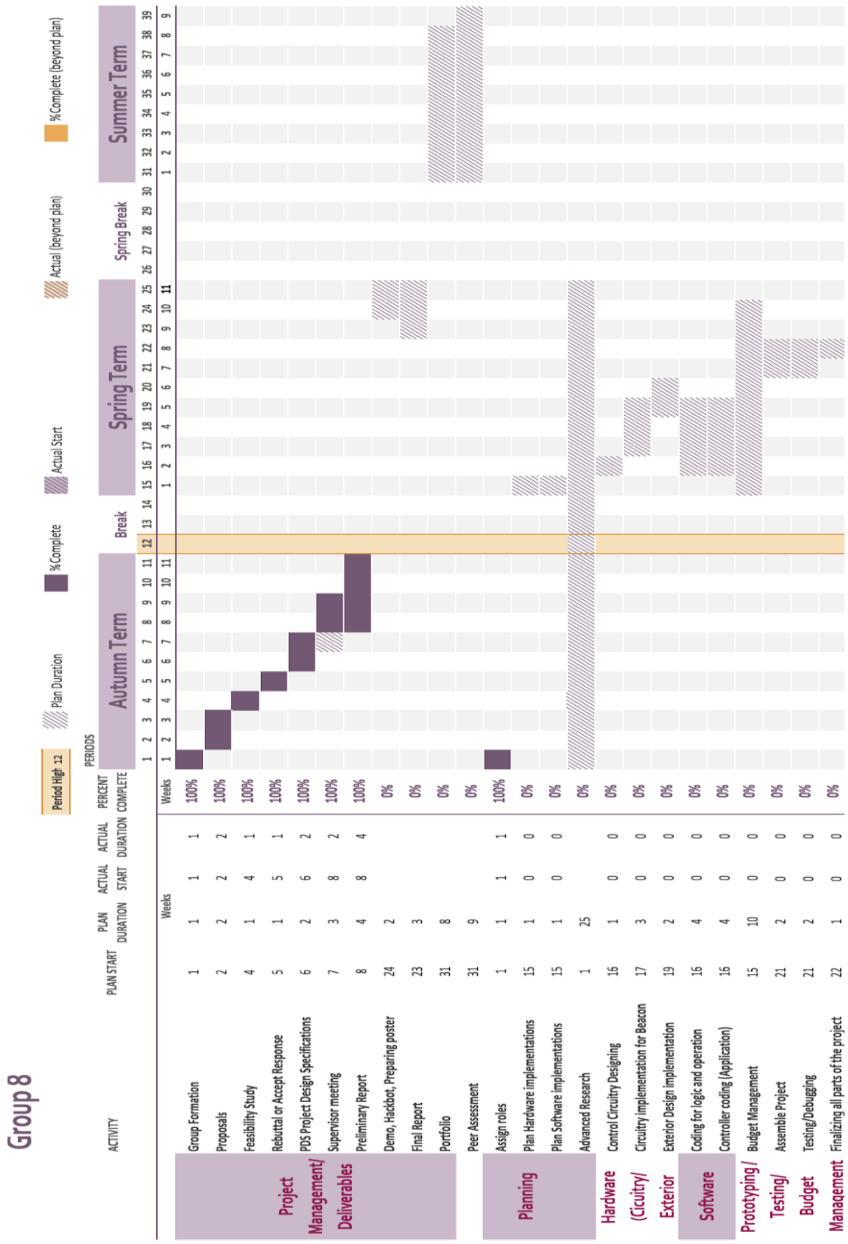
When passing through airport security users may need to detached the belt, which can be cumbersome for the users to take off and put back on the device.

Estimated Cost

Name of the component	**Cost(£)**
HMC6352-TR Honeywell Compass Module	3.67
Palm Grove Woven Belt	6.99
Vibration Motor (Requires x 8)	13.62
Vishay 1N4001-E3/54 Diode, 50V 1A, 2-Pin DO-204AL (Requires x 8)	1.92

Vishay 100nF Multilayer Ceramic Capacitor MLCC 50V dc ±10% X7R Dielectric Radial, Max. Temp. +125°C (Requires x 8)	9.6
2N2222 SILICON NPN TRANSISTORS (Requires x 8)	12.4
Resistor, 1W 5% 1K - MCF 1W 1K (Requires x 8)	0.56
ERG-2SJ470 - RESISTOR, 47OHM, 2W, 5%, AXIAL (Requires x 8)	3.2
Total	51.96

Gantt Chart


Group 8
Period Highlight: 12
Plan Duration
% Complete
Actual Start
Actual (beyond plan)
% Complete (beyond plan)
ACTIVITY
PLAN START
PLAN DURATION
ACTUAL START
ACTUAL DURATION
PERCENT COMPLETE
PERIODS
Autumn Term
Break
Spring Term
Spring Break
Summer Term
Weeks
Project Management/ Deliverables
Group Formation 1 1 1 1 100%
Proposals 2 2 2 2 100%
Feasibility Study 4 1 4 1 100%
Rebuttal or Accept Response 5 1 5 1 100%
PDS Project Design Specifications 6 2 6 2 100%
Supervisor meeting 7 3 8 2 100%
Preliminary Report 8 4 8 4 100%
Demo, Hackbot, Preparing poster 24 2 0%
Final Report 23 3 0%
Portfolio 31 8 0%
Peer Assessment 31 9 0%
Planning
Assign roles 1 1 1 1 100%
Plan Hardware implementations 15 1 0 0 0%
Plan Software implementations 15 1 0 0 0%
Advanced Research 1 25 0%
Hardware (Cicuitry/ Exterior
Control Circuitry Designing 16 1 0 0 0%
Circuitry implementation for Beacon 17 3 0 0 0%
Exterior Design implementation 19 2 0 0 0%
Software
Coding for logic and operation 16 4 0 0 0%
Controller coding (Application) 16 4 0 0 0%
Prototyping/ Testing/ Budget Management
Budget Management 15 10 0 0 0%
Assemble Project 21 2 0 0 0%
Testing/Debugging 21 2 0 0 0%
Finalizing all parts of the project 22 1 0 0 0%

Selected Concept and Next Step

From the high level design solutions we have devised, we have chosen to develop High Level Design 5.

Out of all the possible solutions listed, this was proven to be the most feasible when factoring in time constraints, costs, and technical feasibility. In addition, its application goes beyond just assisting blind people navigate the airport, without the haptic belt and audio feedback, the design can be used for non-visually impaired people. It can easily be implemented onto other indoor areas, making the design versatile and adaptable. As for the users, they will receive minimal attention from the public as they would be able to navigate simply through the feedback from the belt and audio. The belt can be worn underneath their attire. The combination of audio and haptic belt feedback makes it such that the user can get a clearer navigational indication.

Going forward, the project planning is outlined as follows: The Gantt Chart provides a timetable for the group to follow. Over the Christmas Break, advanced research for non-taught requirements and learning skills necessary for the solution will be conducted. Focusing primarily on BLE beacons and using it to determine the user's location and mobile application development. Group roles had already been assigned. The group is divided into two subgroups; one for hardware and the other for software. The software team consist of four members and will focus on creating the mobile application. Hence, will handle the following tasks: programming the application for the user interface and mapping logic with signals from the beacons. The hardware consists of three members and will focus on developing the haptic belt, undertaking the following tasks: circuit and exterior design of the belt. Each team will conduct relevant testing throughout the development stages. There is an overlap between the two teams during the integration stage. Once the prototype is completed it will be tested to see it is fully functioning. Debugging and running tests for the demonstration, creating the poster and writing the report would also have to be done around March. Meetings will be conducted once every week to ensure everyone is updated as to what the subgroups are doing and the progress they are at. The hardware team will work on the circuitry during Wednesday afternoon. Meetings with our supervisors will be set up at least once every two weeks to keep him informed regarding the progress of the project.

The main objectives for January:

- Do research on unknown skills and knowledge and start planning on software and hardware implementation.
- Have the hardware team will finalize the design component choices by the first week of spring term. The components will then be ready to purchase by the second week of spring term.
- Assign a subgroup leader to lead the team and set up their own deadlines and deliverables for the subgroup

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