Imperial College London

EE2-PRJ E2 PROJECT

INTERIM REPORT

SMART BICYCLE WEARABLE

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1. Abstract

In this report we will introduce the underlining concepts of out project. The purpose of the project is to provide an effective and viable solution for bicycle riders to use when they navigate in an urban environment. The group has come up with a variety of different designs that can be incorporated into either a vest or a helmet for the rider. The report will analyse both solutions with respect to the method of master-slave modules communication, cost, control, power and ease of use. Finally we discuss the results of our analysis and propose a design for further testing.

2. Introduction

Traffic congestion, environmental concerns, physical health and joy encourage residents of big cities to commute by bike on a daily basis. Nonetheless, the security is questionable. According to official data[1] cycling casualties in UK in 2013 reached a total of 19,438; 109 deaths and 3,143 serious injuries. Most cyclists do not have the necessary equipment to alert vehicle drivers prior to their turns or stops. Variety of alert systems is commercially available, but most of these systems consist of simple lights that are not integrated with the bikes and should be removed after use in order to avoid theft. Moreover, a simple combination of small LEDs is not sufficient for change in direction alerts, so cyclists ought to use their hands for this purpose, causing discomfort and in extreme cases imbalance. Additionally there is an increase in the demand for navigation guidance for cyclists due to the complexity of the roads of the big cities and the fact that the vast majority of the population has been familiarised with navigation technology the past years. Nonetheless, commercial navigation systems for bikes use a screen display that attracts the attention of the rider, increasing the risk.

The advent of wearables encourages the development of a vest or a helmet for cyclists that would be equipped with smart technologies in order to address the previously mentioned difficulties regarding security as well as satisfy the needs and comforts of the users. Navigation signals will be converted into haptic feedback to facilitate and secure riding.

3. Design Criteria

The product must be wearable and not be a part of the bike, since the cyclist can use the same device with different bikes (i.e Santander Cycles, multiple personal bikes). It has to be waterproof and if a vest is finally implemented it should be washable. Additionally, the alert system had better have a relative wide range in order to be visible from distance. Output signals ought to be in tactile form, such as vibrations. Like every wearable device, it would rather be lightweight and comfortable. In addition, in order to eliminate extra weight, a power efficient and independent design should be implemented to avoid additional weight from batteries and generators. Please refer to the Appendix A for a complete list of specifications.

4. Market Research

The idea of specially developed navigation systems for cyclists is not a newborn concept. Nonetheless, the commercial devices are mainly optical, the user has to be focused on a screen, they are integrated into the bike, they are not removable, and they are particularly expensive, usually a few hundreds of pounds, unaffordable for hobbyists.
A few related devices are listed below.

Hammerhead One	Garmin Edge 810	BeeLine Bicycle
Guide the cyclists through their route by intuitive light signals.	Touchscreen GPS bike computer with maps, navigation and advanced performance	BeeLine simplifies the directions down to an arrow and the distance left to go It is like a compass that points only to the destination.
Optical	Optical	Optical
Removable	Removable	Removable
£120	£455	£98

TABLE 1: COMMERCIAL PRODUCTS

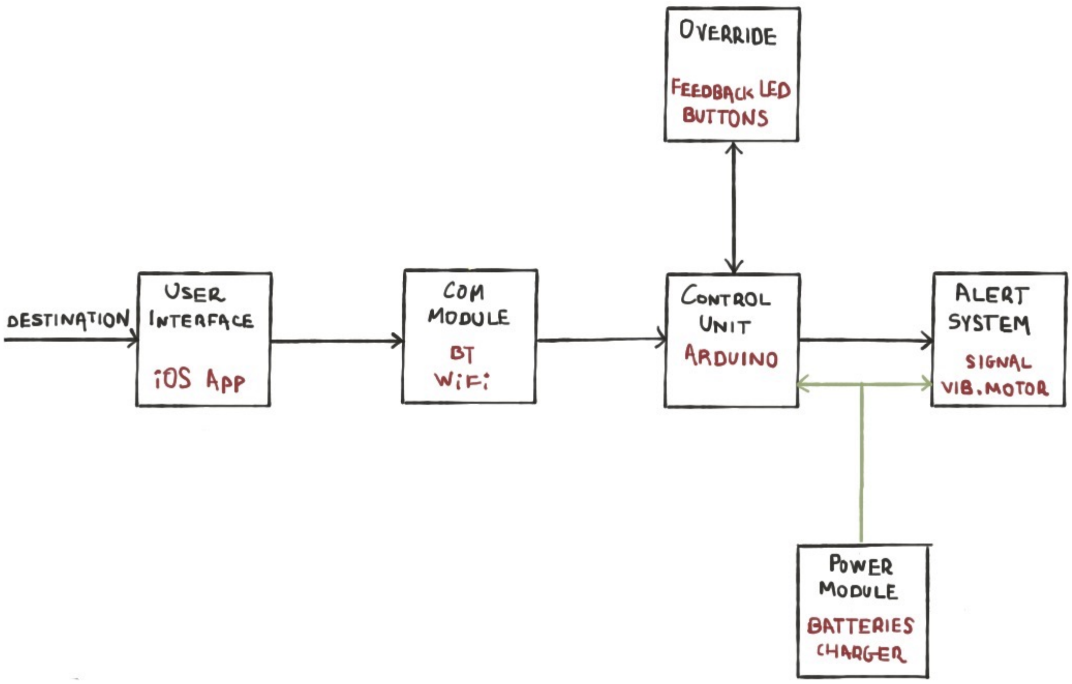


FIGURE 1: SYSTEM LEVEL DESIGN

5. Concept Designs

In order to generate its preliminary designs, the group followed the technical specifications of the PDS. The physical implementation of the design in terms of dimensions, shape and positioning were considered first. In addition, multiple implementations of the electronic parts were developed and they are compared below. The core of the design comprises of the control module (navigation system and haptic feedback signals generation) that does not depend on the shape of the final device and can be analysed separately. A general system level design (figure 1) that describes abstractly the operation of the device is displayed on the previous page. Please also refer to the Appendix B for the estimated total cost of the device.

A. Wearable

The haptic feedback navigation system will be integrated into a wearable device. Taking into consideration the PDS, the alert system has to be: power efficient, lightweight, waterproof and affordable. The team concluded the design should be based on equipment that is already used by cyclists in order to not introduce brand new devices that may be rejected by cyclists' community. The two possible designs are described below.

I. Vest

A combination of discrete LEDs and vibration motors can be integrated to a bicycle vest (Figure 2) for notifying drivers to rider's imminent actions (i.e. right/left turns, braking, stops). The electronic parts can be kept in a specially designed waterproof pocket.

Estimated Cost £32

II. Helmet

Alternatively, the alert system and the tactile feedback system can be designed for a helmet (Figure 3). Either discrete LEDs or a bendable LED tape can be used for notification signals, while vibration motors can be placed inside the helmet.

Estimated Cost £25

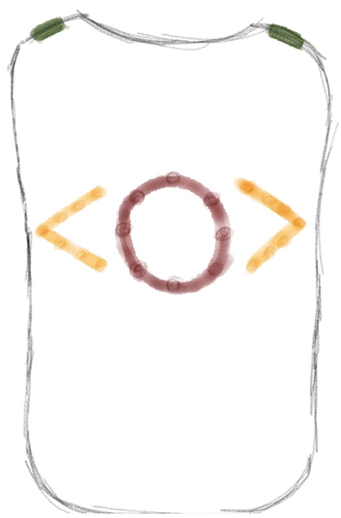


Figure 2: Smart Bicycle Vest

Figure 3: Smart Bicycle Helmet

B. Communication Module[2]

A wireless communication module is essential in order to link the User Interface (iOS Application, user input) to the control unit. It would be possible to use wired technologies, though it would be inconvenient and anti-aesthetic. Bluetooth and WiFi technologies were taken into consideration.

The difference between the two mainly stems from what they are designed to do and how they are used. On one hand, Bluetooth is primarily used to connect devices without using cables, while WiFi mainly provides high-speed access to the Internet.

Bluetooth is a wireless technology standard that is used to exchange data over short distances (less than 10m), usually between personal mobile devices. Bluetooth acts like a cord between the two devices by creating a secure, wireless personal area network in which these devices can communicate. Modern Bluetooth Smart technology makes possible a Low Energy protocol (BLE) that significantly reduces the power consumption.[3]

WiFi has some similar applications to Bluetooth, such as setting up a network or printing and transferring files. It is also a wireless standard, which instead of being designed to communicate between devices, it serves to wirelessly connect devices to the Internet or Ethernet networks such as a corporate local area network (LAN). Its range is quite a bit larger than the very short range within which Bluetooth devices communicate, as a WiFi signal can be picked up to 100m away. This means that a WiFi-enabled device, such as a PC or smartphone, can connect to the Internet wirelessly when in a WiFi "hotspot," or area in which a WiFi signal may be accessed.

Estimated Cost £5

C. Control Module

As far as braking signals are concerned, an accelerometer will be used to measure the acceleration of the bicycle. If the instantaneous acceleration is greater than a threshold value (defined after experimentation) then the braking red light will switch on.

On the other hand, the control of the alert system (vibration motors and light signals) is directly linked to the output signals generated by the mobile application. The three best solutions are explained below.

Estimated Cost £8

I. Compass Orientation

This implementation is based on geographical orientation. The user enters the destination and the program calculates the position vector from the current location to the destination point. This vector is regularly calculated and the application provides as output the angle of this vector. This angle is compared to the orientation of the cyclists that uses the compass of the mobile phone. As long as the difference of these two angles is within limits there are no alert signals. When the difference exceeds a reference value, haptic feedback is provided to the user to guide him/her to the desired destination.

This implementation lacks turn-by-turn navigation since it does not use any map databases. It is ideal though for hobbyist cyclists that like riding around cities and do not like following turn-by-turn instructions.

II. Signal Processing

Instead of developing a navigation system from scratch it is possible to use already existing navigation systems to our advantage. By developing a program that receives audio signals from Google Maps and manipulating these signals to control the alert system a very robust and simple tactile navigation system can be designed.

This solution is very effective, since it combines the positive aspects of the complex algorithms developed by big navigation companies (TomTom, Google), the frequent bug fixes released by them and the simplicity of an embedded system.

III. Haptic Turn-By-Turn Navigation System[4]

A turn-by-turn navigation system can be developed to directly provide haptic feedback. It communicates with a Web server and constantly receives instructions for the navigation.

It is a standalone solution that can be fully configured by the team, since it is developed from scratch. Nonetheless, it is much more complex to realise and involves advanced software engineering considerations.

D. Power Unit

The electronic parts will be powered by a lithium ion polymer battery 3.7v 150mAh. It was chosen because of its small size, light weight and recharge-ability.

Estimated Cost £8

6. Discussion

A brief comparison of the different designs follows.

A. Wearable

The team believes that the smart helmet is a better choice since it outmatches the vest in some key points. Namely the user's movements are not restricted by the use of the helmet as much as with the vest. In addition, the use of the helmet indicator lights is less complex than the ones in the vest, which might require the user to wear the vest on top of a backpack or jacket. Moreover, the vibrating navigation indicators in the vest might destabilize the user and cause an injury, while on the helmet the user remains in balance. For these reasons the team believes that a smart helmet would be a better solution to the issue our team is trying to tackle.

B. Communication Module

In our application, Bluetooth seems to be more appropriate since the additional capabilities of WiFi are not required. Distances are very short and only a simple pairing is required. Bluetooth hardware and software are widely available on every platform and APIs are freely available. On the other hand, development on WiFi is slightly more complicated since it would require some socket based code to be written and the security (WPA) would need to be configured. Furthermore, to achieve its longer range, WiFi would require more power from the device batteries.

C. Control Unit

Inarguably, the control module comprise the core and most challenging part of the design. Right now, there is a working prototype of the "Compass orientation" implementation while two teams are working on the other two possible solutions. The "Signal Processing" solution seems more straightforward and its implementation is viable under the given circumstances (available time, knowledge, resources). On the other hand, the "Haptic Turn-by-Turn Navigation System" is less possible to be successfully developed due to complexity and legal restrictions imposed by companies that develop public maps (Google, Skobbler, TomTom).

7. Conclusion

Cycling in big cities has been proved to be a very dangerous mean of transport, or hobby for some. The group identified two significant issues which make the use of bicycles in big and central roads dangerous. The former is the fact that unlike motorbikes and vehicles, the cyclist does not indicate their turns to the rest of the drivers, while the latter being the lack of a safe navigation system, which would notify the rider where to go, without the rider's need to take their eyes off the street. In order to give an end to this problem, our group came up with the Smart Helmet, a helmet, equipped with three LED arrays (two for direction and one for braking) and vibrators to inform the rider where to turn. Until now, the communication and control modules are under development since many different approaches on their realizations are still being considered and processed. All in all the Smart Helmet is an implementable design which will make people reconsider everyday use.

8. Appendix

A. Product Design Specification

I. Performance

The product must be wearable and not be a part of the bike, since the cyclist can use the same device with different bikes (i.e Santander Cycles, multiple personal bikes). It has to be waterproof and if a vest is finally implemented it should be washable. Additionally, the alert system had better have a relative wide range in order to be visible from distance. Output signals ought to be in tactile form, such as vibrations. Like every wearable device, it would rather be lightweight and comfortable. In addition, in order to eliminate extra weight, a power efficient and independent design should be implemented to avoid additional weight from batteries and generators.

II. Environment

The materials of the product will be chosen so that they don't harm the environment during their period of use or their disposal. In addition, the light pollution produced by our device is projected no to have any serious impact on the total light pollution of a city.

III. Maintenance

The maintenance of the product will be as simple as possible, so that it will be easier for the cyclists to maintain their smart wearables. For example, the battery for the product must be charged or replaced easily. As far as the helmet implementation goes, there are no maintenance concerns. On the other hand, the time needs to design smart vest to make it washable without damaging the electrical components in the vest. This can be achieved by designing a smart vest in which the electrical components and the vest are separable and can recombine easily after washing.

IV. Target Product Cost

The product is aimed to be affordable to every cyclist. Hence, the target product cost is expected to be relatively lower compared to the current competitors such as Garmin. The target product cost which is also based on the cost of the product, will be finalised when the design is completed.

V. Competition

At the moment there are several competitors with products similar to some aspects of the Smart Vest. However, none of them combines haptic feedback navigation with the safety part simultaneously, which gives a tremendous edge to our design.

VI. Quantity[5]

As our product is new on the market, the cyclists in London will be our main target. According to BBC, there are about 610,000 cycling journeys every day in London. Based on this data, we are expecting to release around 5,000 units to test the response of the market.

VII. Manufacturing Facilities

The manufacturing facilities will be based in or near London as our primary market target is London. The size of the manufacturing facilities will grow depending on the demand for the product.

VIII. Size

Smart Vest will come to various sizes (Small, Medium, Large and Extra Large). The size of the LED array is 20cm*20cm so that it can be clearly visible and the size of the control unit must be small so that it does not make the rider uncomfortable. The vibrating bracelets are the size of a mean human wrist.

The helmet will come to two sizes (47-55mm, 56-64mm), the normal sizes for an adult helmet since the LEDs will not occupy more space on the design.

IX. Weight

The weight of the smart vest should not exceed the weight of a simple vest/helmet by more than half a kilogram, so the whole product will be easy to be carried and used. Also, the bracelets are quite light and the LED arrays that will be used for the helmet have negligible weight, both facts that rise no more weight concerns.

X. Aesthetics, Appearance & Finish

The products should have variations in colour in order for the cyclists to choose their favourite colours. However, the colours must be striking and outstanding to ensure the drivers can detect the cyclists easily on the road. Fluorescent colour is the best option as it glows in the dark too. It should be aesthetically pleasing, since everyone loves cool and nice design.

XI. Materials

Materials to be used must be as reliable as possible. For example, it must be light-weighted, so the cyclists do not feel the extra weight from the smart vest which can endanger the cyclists. The materials must be durable under the exposure of weather. Their price must also be affordable to avoid exceeding the budget.

XII. Product Life Span, Quality and Reliability

- The maps used for the navigation will be based on reliable platforms (i.e Google Maps, TomTom) that provide frequent updates with improvements and bug fixes

- The user will be provided with a simple guide for restoring the device to its default settings, recovering any software failures
- The life span of electronic parts is very long, as a consequence if the user respects the given instructions and protects the device (i.e follow washing instructions, carefully removal of electronic parts) the product should have a long life

XIII.Ergonomics

The product will be designed in such a way that it does not cause any restriction in the cyclist's movement. Dangling wires and cables will also be avoided as they are likely to induce accidents. Moreover, the vest/helmet and its accessories need to be comfortable to wear (light in weight and flexible) to optimise the performance of the cyclist.

XIV.Customer

Smart Vest's main target group is cyclists of big cities where the traffic renders biking extremely difficult and dangerous. Other cyclists can also make use of the product to increase their safety and be easily navigated to their destination.

XV.Shelf Life

Due to the electronic nature of the product and the lack of moving parts, the expected shelf life is estimated to be around 6-10 years based on moderate estimations of the LED shelf life. In that estimate we don't incorporate the battery shelf life which may be considerably shorter depending on the type and manufacturer of the battery pack.

XVI.Process

At this stage the device will be assembled manually from already existing components, if there is a high demand then a manufacturing process should be adapted.

XVII.Life In Service[6]

Our design has long life duration as LEDs can last for more than three years as the estimated lifetime of LEDs is about 2000 hours. The control unit and the navigation system can last for much longer. It should be noted that the above apply, if the device is used appropriately and according to the given specifications.

XVIII.Time-scale

The time scale of this project is equivalent to the deadlines of the projects:

A. Team Building: 21st October 2015
B. Interim Report: 17th January 2016
C. Final Report: 13th March 2016
D. Website: 13th March 2016
E. Presentation and Demo: 22nd March

XIX.Testing

Once the internal mechanism of the product is ready, it will need to be tested. The first testing step will be test whether the LEDs and the vibrators respond to different outputs of the control unit. If not, the communication between the Smartphone and the control unit, as well as the code for the vibration and the LEDs will have to be reviewed. When the above are completed successfully, one will have to test the vest while walking on the road and as a final test to use it when cycling, to ensure the rider's safety.

XX. Safety

The rider is completely safe when using the device as it will help him know where to go without having to take their eyes off the road. Moreover, the LEDs will indicate the rider's intentions to the surrounding drivers early enough before the movement. Additionally, the use of the vest is completely safe with reasonable use.

XXI. Company Constraints

Many constraints arise regarding the implementation of the project due to the tight budget of the project. Also, another problem the team has to overpass is the way the control unit will communicate with the navigation application because at the moment there is not a turn-by-turn navigation SDK.

XXII. Market Constraints

As far as the helmet option is concert, it must satisfy the Safety Criteria imposed by each country in order to be used (i.e UK Government does accept every design, no restriction is imposed)

XXIII. Patents, Literature and Product Data

- Automatic Activation of Turn Signals In A Vehicle[7]
- Navigational tool with drag-based tactile feedback on a handheld wireless communication device[8]

XXIV. Social Implications

The implications to the society will only be positive as cyclists will finally be able to move inside crowded cities safely and without risking getting hurt while trying to realize where they have to turn to reach their destination.

XXV. Standards, Specification & Legal

N/A

XXVI. Installation

- In terms of the vest, the user should follow the instructions provided in the user manual for the initial installation of the electronic parts as well as the careful removal before washing.
- As far as the helmet goes, the electronics are integrated in the helmet and there is no need for further installation

XXVII. Documentation

Product documentation must be clear and informative. Product documentation ought to be written in English as it is an international language. A native language can be added depend on which country the products are exported to. It had better illustrate the instructions for the product in cliparts or drawings to accommodate the needs of cyclists who are illiterate.

XXVIII. Disposal

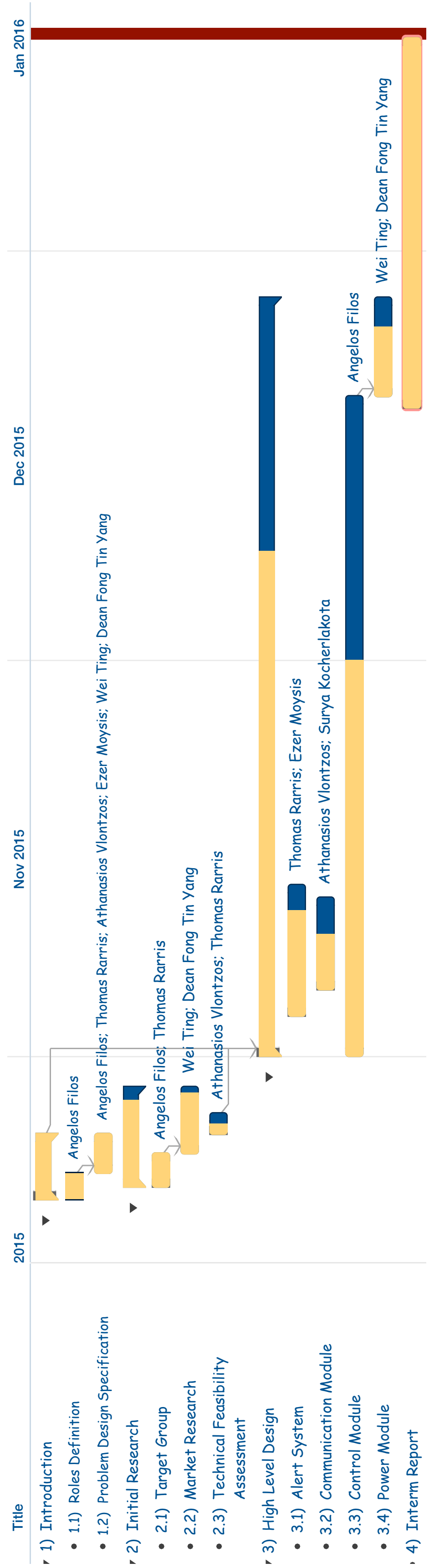
An effort will be made for the materials to be as recyclable and reusable as possible to minimize the effects to the environment. The standard electronics disposal methods can be used for the product, since it wont contain any sensitive or toxic substances.

B. Total Estimated Cost

<table>
<tr><th>Smart Bicycle Helmet</th><th>Smart Bicycle Vest</th></tr>
<tr><td>Helmet £25</td><td>Vest £32</td></tr>
<tr><td colspan="2">Arduino Gemma £8</td></tr>
<tr><td colspan="2">Lithium Ion Polymer Battery £6</td></tr>
<tr><td colspan="2">Bluefruit LE UART Friend £5</td></tr>
<tr><td>£44</td><td>£51</td></tr>
</table>

Table 2: Total Cost

C. Gantt Chart



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