Final Year Project Interim Report
The Sixth Sense - Electronically Augmented Perception

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Abstract

The human brain processes vast amounts of information about the world around us using signals from our biological senses; sight, hearing, smell, taste and touch. The development of small, low power electronic sensors give rise to the possibility of extending a person's perception of the world around them to include additional information that would otherwise not be available to them. Not only does this provide the opportunity to replace or extend our current senses but also to create completely new senses. This paper proposes a piece of wearable technology to communicate a sense of direction, through GPS navigation, to the brain via the channel of touch.

1 Introduction

Our brain is constantly overloaded with information about our surrounds, receiving and interpreting signals from our biological sensors, it is able to form a picture of the world around us. However, our perception of the world is limited by the types of information we receive from our senses, for example we are only able to detect waves in the visible light range of the electromagnetic spectrum and only sound waves in a small frequency range. In order to discover more about our environment we need different sensors to capture new information.

With the development of technology, we have attempted to increase the amount of information we can access, using the internet and smart phones to have any information we need at our fingertips wherever we go. However, the majority of technology relies on displaying this information to be captured by the sense of sight. This results in a problem, in order to retrieve information from these different sources we overload our sense of vision, making us less able to use our most dominant sense [1] for its original purpose.

A recent safety problem that we face today is the use of mobile phones affecting the awareness of activities in their environment. Recently a US study found that the number of pedestrians treated in hospital emergency care due to the use of mobile phones has increased dramatically [2]. A particularly topical example of these occurrences is the recent emergence of the game Pokémon GO. The game led to a large rise in the number of accidents and injuries resulting from people concentrating on their mobile phones and not on what was going on in the world around them. Many people were involved in road traffic accidents because they did not see oncoming traffic, or obtained injuries from walking into obstructions, tripping and falling or unintentionally walking into dangerous areas such as cliff tops [3].

Many of these injuries occur when pedestrians are using their mobile phones in areas of traffic. A common case of this is the use of GPS navigation mobile phone applications, pedestrians are often unfamiliar with the area and so focused on the map or directions their phone is displaying to them that they are unable to pay enough attention to the traffic. In order to improve the safety of pedestrians navigating unknown areas this paper proposes a wearable device with the purpose of transferring information usually obtained by vision, in this case a navigational aid such as directions on a map, to another sense, releasing the users vision to detect dangerous situations such as traffic.

The idea presented in this paper is to use the sense of touch, a sense which is not receiving large amounts of information nor playing a significant role in the detection of danger, i.e. traffic, in this situation, and so is an available channel of communication in the brain. The sense of touch can be exploited in 3 different ways; stretch, temperature and intermittent pressure i.e. vibration. The detection of temperature by the skin has poor localisation and temporal acuity whereas objects that can apply stretch are not compact and so would not be suitable to be embedded in a wearable. However methods for applying vibration are inexpensive, commonplace and small making them an ideal solution for use in a wearable device.

The prototype device will be formed of a wearable with embedded vibratory motors controlled by an application running of a mobile device. An important factor of the project is to make the wearable independent of the application by making a well defined communication interface between the mobile phone and the microcontroller in the wearable, allowing the possibility of the wearable being used for other applications. The application designed to communicate the new sense will be a GPS navigational aid to relay directions to the user via the vibratory motors.

2 Background

The brain is incredibly complex and is able to use signals from our biological sensors, such as our skin and eyes, to perceive the world around us. However, these signals are only capable of detecting a very small subset of all the information available in our surroundings, for example our eyes can only detect visible light which only makes up a tiny portion of the electromagnetic spectrum. Despite our natural sensors limiting the information we can sense, the brain has the capability to interpret streams of data that are unfamiliar, communicated via existing channels [4]. An example of this is the use of retinal implants to restore the sight of blind patients. The implant stimulates the retinal nerve cells with an approximated signal to imitate the signal that a healthy eye would send and, even though the signal is not identical to that which the brain would receive from an eye, after a period of time the brain is able to interpret the signal and restore vision to the patient [5].

The ideas behind replacing or extending senses is not a new concept, in 1969 a team at the Pacific Medical Center in San Francisco ran an experiment to find if visually impaired people could have the sense of sight restored in an alternative way [6] . The subjects sat in a modified chair with a grid of solenoids controlled by the video feed from a camera. An object would be placed in front of the camera and the solenoids would form a tactile pattern which the subjects would feel through their lower back. After a number of training hours, the test subjects were able to distinguish an objects from a selection of 25 common objects such as a chair or a cup.

This idea from Bach-y-Rita has been extended towards a smaller and more mobile solution using an electrotactile grid on the forehead to communicate the view of the surrounding world [7]. The electrotactile grid has also been used for other purposes such as alerts from the wearer's smart phone [8].

Instead of replacing sight with touch, there have been a number of investigations into replacing sight with sound, sonic glasses detect the depth perception in front of the wearer and produce sound to indicate that view [9]. With training 90 percent of the test subjects found the glasses to be useful for their mobility [10]. This idea has even been extended to guide and help visually impaired people navigate around objects in their environment [11].

In the reverse situation the visualisation of sound has also been used to help people with impaired hearing to visualise the sound in the world around them [12]. An extension to this concept is the Invisibilia project [13] which goes further, visualising sound for subjects with no hearing impairment, using sight to aid understanding of sound. The Invisibilia project uses a virtual reality (VR) headset to display data from the outside world that we cannot see. In this specific case sound waves from a radio are displayed, the wearer can manipulate and interact with the sound waves using intuitive hand gestures. The idea behind the project was to allow someone to remotely demonstrate how to use equipment, to provide visual cues and demonstrations rather than simply attempting to describe to the user what to do. The Invisibilia prototype was made from a VR headset and a mobile phone with a camera and depth sensor used to track the users hands. The prototype was tested in an experiment where subjects were asked to interact with a radio which could be operated by hand gestures or by manual control. The image of the sound wave output by the radio was superimposed on the camera image and displayed by the VR headset, the subject could then stretch and pinch the sound wave image to change the pitch and amplitude.

The aim of the experiment was to see how intuitive gestures could be used to learn about sound wave physics.

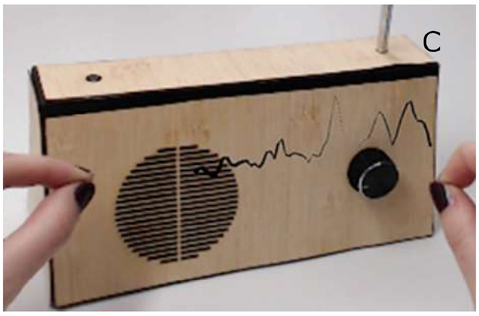

Figure 1: The image projected by the VR headset in the Invisibilia project [13]

More recently, with the development in electronics making sensors and actuators significantly smaller and more portable, projects to replace senses have become even more complex. Using the research outlined in their paper on the use of vibration as a method of relaying information via touch [14], Novich and Eagleman created a prototype wearable device to be a non-invasive and low cost device to allow those with impaired hearing to understand auditory information [15]. Sounds were translated to patterns of vibrations of vibratory motors in a wearable. This product offers an alternative to the cochlear implant which requires invasive surgical implantation and is around 40 times more expensive [16].

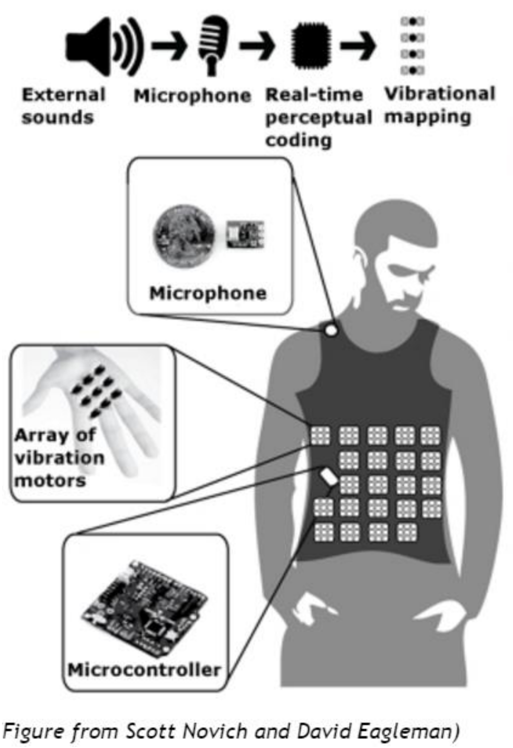

Figure 2: The wearable vest implemented by Novich and Eagleman for sensory substitution [14]

The ability of the brain to interpret new signals provides the opportunity to extend our perception of the world around us through the use of additional sensors. This results in possibilities, not only to replace senses that have been lost or damaged but, to extend our current senses or create entirely new senses, collecting information about our environment using electronics and communicating these new signals to our brain via existing channels.

There have been a variety of projects investigating the extension of our senses, primarily focusing on the extension of vision as it is often identified as our most dominant sense [1]. SpiderVision [17] is a wearable device that extends the range of human vision to allow the wearer to see behind them without confusing the them or distracting from their normal view. Although vision is the most dominant sense, it only covers about a 200 degree sweep in front of the person. The prototype uses a virtual reality (VR) headset with front-mounted and back-mounted cameras. The headset displays the view from the front-facing camera, the image captured by the rear-facing camera is analysed for approaching objects and this activity is blended with the front-view image. There have been various different projects to attempt to extend the range of human sight. FlyVIZ uses a head mounted display to display the image from an omni-directional camera [18] meanwhile Virtual Chameleon uses two cameras which the wearer can control independently [19]. However both of these projects require the user to use significantly more effort to understand due to a large amount of extra visual information to process. The advantage of SpiderVision is that it does not distort the normal view of the user and only extends the field of vision when there is relevant information in the areas outside the normal field of view.

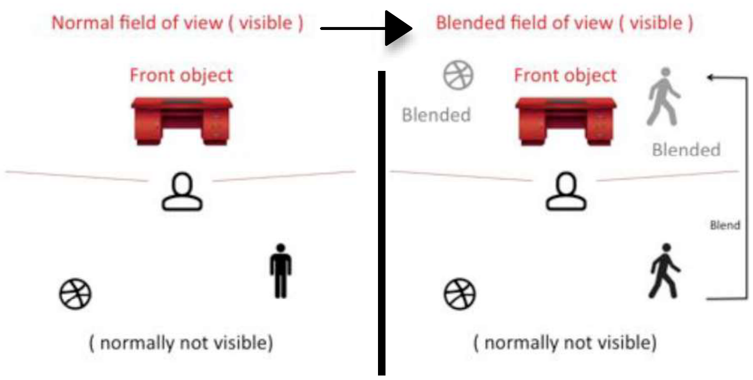

Figure 3: Spidervision sight extension diagram [17]

In a similar project undertaken by Mateevitsi et Al. [20] the user would only see the front view but would be notified of objects outside the normal field of view approaching. The possible uses of the device included compensating for damaged or missing senses or to extend existing senses such as assisting the user in navigating while avoiding obstacles or communicating a sense which is overloaded through another. The opportunity to communicate information from a sense which is overloaded via another sense offers many possibilities for improving the safety of people by enabling them to change the way in which they detect information, freeing up the overloaded sense.

3 Design

3.1 Wearable Device

Wearable technology allows us to use the skin as a technology-brain interface. As wearable technology becomes more mainstream, investigation into the sensitivity of our natural sensors has become increasingly important. There are multiple different aspects that need to be considered in the design of a wearable, such as practical considerations of location of electronics and maintainability of the device as well as the way in which they will be attached [21]. Among the most important aspects of wearable design is the placement of the vibratory motors and the way in which they communicate information [22] [23]. Also of particular importance in this case, due to the proximity of the vibratory motors to the skin, the thermal properties of the device must be taken into account as well as flexibility and durability of the wearable [22] [24].

3.1.1 Requirements

Location The vibratory motors will be integrated into a piece of clothing in contact with the skin.

The best areas of the body to use for skin interfaces are large areas of skin that are of a similar size across all adults and that experience little movement when the body is in motion

[25], such as the back, the back of the hand or the neck. In the work of Novich and Eagleman [14] the lower back was investigated as a suitable area for using vibratory motors as a method of communication. They successfully used the area of skin of the lower back [26] in their prototype device for sensory substitution, finding the area effective for relaying information to the brain with a optimal resolution of at least 6cm. The lower back area is also particularly suitable as it is less prone to wrinkles and folds which could change the effectiveness of the interaction and the added weight of the device should be placed as close to the centre of gravity as possible to make it more comfortable and unobtrusive to wear [25]. Bach-y-Rita also identified tactile effects on the lower back as a suitable sensory substitution touch location [6].

It is important to consider the mobility and flexibility of the device. The device must not restrict movement or cause any discomfort to the wearer when they are conducting normal movements, such as walking. However, as the wearer moves the vibratory motors must remain in place relative to the skin. In order to remain in place and not cause any discomfort the device must be flexible so as not to inhibit movement of the body but to remain in the same position on the skin.

Size and Weight The device needs to be very light weight so as not to be an encumbrance or cause annoyance. It must also be small and not bulky as it is to be worn underneath normal clothing.

Attachment All of the electronics will be attached to the garment so that it can be easily put on and taken off, rather than directly to the skin which we require reapplication for every use. This will also avoid the use of adhesives or other methods of attaching electronics directly to the skin which could cause discomfort or injury including allergies or skin abrasions. Avoiding attaching the motors directly to the skin also makes this solution less invasive or obtrusive [27].

Interaction The device will interact using the sense of touch as a channel to relay information to the brain through the use of vibratory motors. A consideration in the selection of vibratory motors is the amplitude of the vibrations being comfortable and accepted by the user but still be informative. Given that different users may have different sensitivity to the vibrations it may be suitable to make the amplitude of the vibratory motors adjustable.

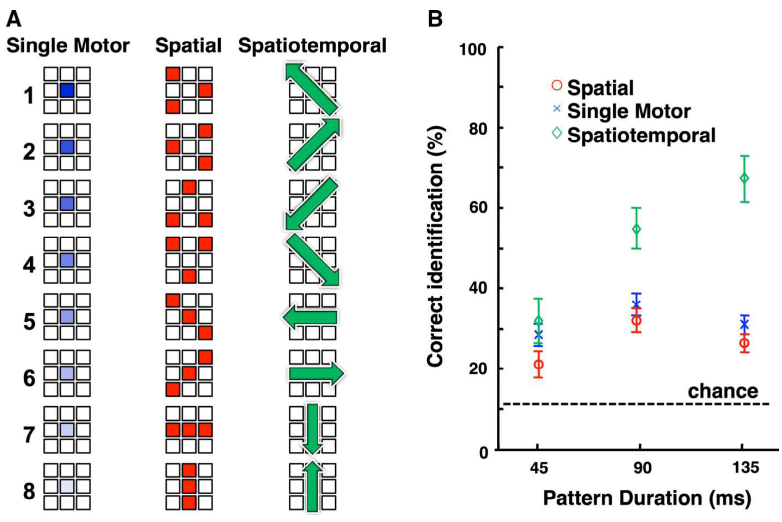

Figure 4: Correctness with which subjects identified spatiotemportal vibration patterns in Novich and Eagleman's experimentation into the suitability of the skin for sensory substitution [14]

In Novich and Eagleman's paper "Using space and time to encode vibrotactile information: toward an estimate of the skin's achievable throughput" [14] it was investigated how touch receptors can be used to communicate information to the wearer and whether they could be used for sensory substitution. The skin has already been investigated for communication of information, for example vibrotactile aids have been shown to be a suitable way of communicating speech or sound in adults with impaired hearing [28]. This paper focused on testing how effective the skin of the lower back [26] is in relaying information and investigating how the use of temporally and spatially encoded vibration patterns can effect how easily the information is understood. The experiments found that the resolution of the lower back was low, needing vibration transducers to be placed at least 6cm apart. Novich and Eagleman concluded that patterns encoded by space and time or by space and intensity were considerably better at communicating information than spatial patterns alone, see figure 4, with spatiotemporal patterns being preferred, see figure 5.

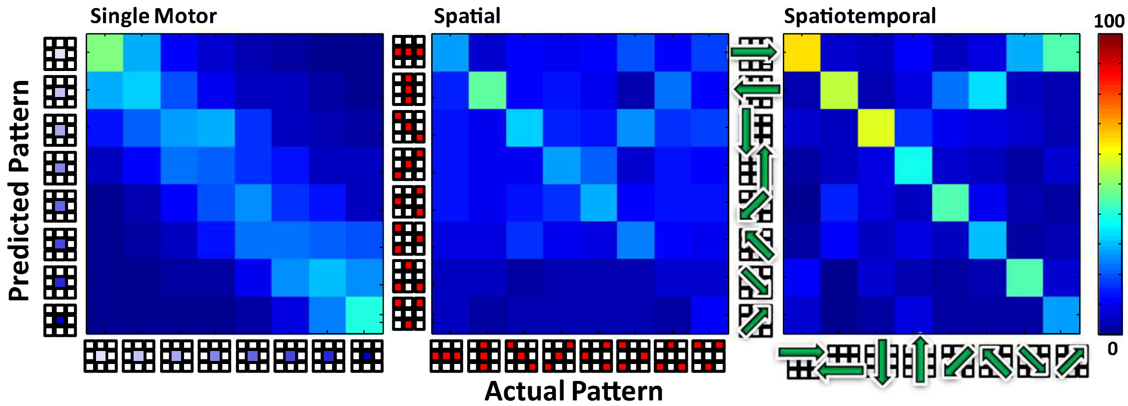

Figure 5: Confusion matrices for spatiotemportal vibration patterns from Novich and Eagleman's experimentation into the suitability of the skin for sensory substitution [14]

Energy The battery does not need to be ultra-thin as it will be integrated in the garment but it will need to be relatively small and lightweight so as not to be noticeable or uncomfortable. For improved usability the battery should be easily rechargeable, for example USB power bank, and hold enough charge for an extended period of use or for multiple uses.

Device Care The garment will need to be washable, therefore the electronic components of the wearable must be easily removed to allow this. However, when making the electronics removable it must not be easy for the electronics to move or fall off when they are attached to the garment and the electronics themselves should be reasonably robust and durable to ensure that they are not damaged in removal and reapplication.

The vibratory motors will not be in direct contact with the skin but encased in a very thin skin-friendly fabric that will insulate the wearer from any small thermal changes and also protect the electronics from moisture. However the encased electronics must be relatively accessible in the case that a component requires replacing.

Communication There will need to be wired communication between the microcontroller responsible for controlling the motors and the vibratory motors themselves, these connections will need to be flexible enough to not cause discomfort but will be embedded into the fabric so will have some support. The communication between the mobile phone and the controller of the motors should be wireless to allow the user to use their mobile phone for other purposes freely while wearing the device. The communication between the microcontroller and the mobile device will need to be reliable and have reasonably little latency as well as being secure. The assumption can be made that the mobile phone will be carried by the user when using the device and therefore that the phone will be in close proximity, allowing short range wireless communication to be used, for example Bluetooth.

3.2 Mobile Application

The sense application is to run on a mobile phone, functioning as a GPS navigational aid to communicate with the wearer of the device a subconscious knowledge of directions. The application will make use of the Application Programming Interface (API) of a preexisting GPS navigation mobile phone app available on the current market.

3.2.1 Requirements

Setup Any setup required for the initial installation of the application will need to be simple and not time consuming. The setup process will require just the registration of the wearable device to setup a Bluetooth connection and user preferences, with any setup or user information required for the wearable being displayed as step-by-step graphical instruction. It must also be taken into account to make the application relatively simple and small so as not to demand too much memory space from the phone as this will be a limited resource.

Usability The application must be simple and easy to use, even for users who have limit technical knowledge. A well-designed graphical user interface (GUI) should be intuitive to use and require few steps to complete the navigational setup, as well as providing suitable feedback to the user such as a progress bar when retrieving a route and displaying an overview of the directions before commencing with the instructions using the wearable. It would also be important to have user details that could be modified, for example to adjust the amplitude of the vibrations so that they are optimal for the user or enabling the user to connect to a different wearable i.e. in the case of the purchase of a new wearable. Other practical concerns include ensuring that application does not save large amounts of data as this is a limited resource on the phone and make the application less energy intensive so as not to drain the battery. A consideration should also be made regarding the personal information of the user, the application should require little personal information and any confidential information should be encrypted when stored and only available to view to the user.

Connection The application will require the phone to be connected to the internet as the direction calculation done by the external GPS navigational application will require an internet connection. However it may be possible to save the directions offline so that the device does not need to maintain an internet connection while the user is travelling. The application will also need to automatically reconnect to the Bluetooth connection between the mobile phone and the wearable should the connection be lost.

Availability Ideally the application would be available to all mobile platforms however the application designed for the prototype made need to be designed for a specific platform for simplicity. However it may be possible to use a platform independent language such as HTML5 to create an application that can run on multiple different platforms. The application should be made publicly available for download via a commonly used supplier such as Google Play.

API The APIs used must have the necessary functionality to provide directions to the application, or to provide a GPS related planned route and then the application will need to track the current GPS location. It would also be an advantage to have the API provide a visual aspect, for example a map or graphic of the directions as a method of feedback to the user. The API should also be able to provide maps and directions saved offline. Suitable APIs include Google Maps JavaScript API [29] , as well as the Google Maps API web services available in Java, Python, Go and node.js. HERE maps provides both JavaScript [30] and REST [31] APIs which allow for pedestrian routing and the Scout API [32] allows for routing and turn-by-turn navigation.

3.3 System Overview

The overall system will be composed of a wearable embedded with vibratory motors controlled by a microcontroller powered by a USB power bank to allow easy recharging. The microcontroller will receive commands to use the motors to create spatiotemporal patterns via Bluetooth communication from the wearer's mobile phone which will be running the GPS navigational aid application.

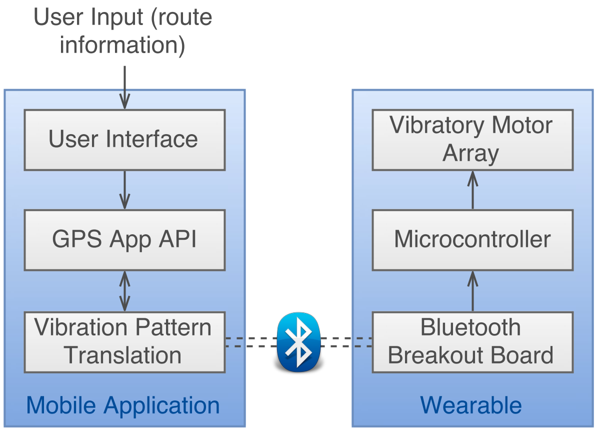

Figure 6: System Overview

The new sense will be communicated to the brain via the channel of touch using vibratory motors as they are cheap and easily obtainable and are relatively low power. The use of vibratory motors also allows the vibration amplitude to be altered, by either using resistors in series or by using pulse width modulation (PWM), which allows the vibrations to be optimised for the wearer of the device to be comfortable but still allow the wearer to detect the information.

The vibratory motors will be arranged in an array to create spatiotemporal patterns, the size of which will depend on the location of the array with respect to the wearer's body. The most likely area for the motors to be placed is on the lower back as it has been found suitable for previous sensory substitution projects [14], however they will also be tested on other suitable areas of the body such as the neck, the back of the shoulders and the back of the hands. Should the lower back be found the most suitable area a 3x3 array will be used with the motors 6cm apart as found appropriate by Novich and Eagleman [14].

The array of vibratory motors will be controlled by an Arduino UNO [33] which contains an ATMEGA328 processor and has enough input and output pins to control the array and is capable of outputting signals using PWM. The microcontroller will be powered by a standard USB rechargeable power bank.

The Bluetooth communication between the mobile phone and the Arduino UNO will be done using an Adafruit nRF8001 Bluefruit LE Breakout Board [34] which allows the Arduino to use UART Bluetooth Low Energy (BLE) [35] to communicate.

For this prototype the project will develop the application for a mobile phone with the Android platform although some of the application may be written using HTML5 which would allow the app to be platform independent. In order to support Bluetooth Low Energy the mobile phone will have to have Android 4.3+.

4 Implementation

Currently the wearable part of the project is close to completion. A 3x2 array of vibratory motors has been created for the location sensitivity testing which can be driven by the Arduino microcontroller using pulse width modulation to alter the amplitude. On completion of the sensitivity tests, depending on the size of the chosen location, the motor array will be extended to enable more complicated spatiotemporal vibration patterns to be used. The maximum number of motors that can be in the array is 12 as this is the maximum number that can be controlled by the Arduino with the Bluetooth breakout board connected. The Arduino can also be connected, via the Bluetooth breakout board, to the mobile phone and is able to receive message strings sent from the mobile phone.

4.1 Implementation Plan

Having already completed the majority of the hardware design and implementation the remaining parts of the project to implement belong to the application, namely the Bluetooth interfacing with the hardware, the use of an external GPS navigational app API and the graphical user interface

(GUI). As well as the implementation of the mobile phone application there must be ample time remaining in the schedule for testing and evaluation of the overall product. The proposed plan of work is shown in table 1.

Table 1: Implementation Plan

Week	**Project Plan**
10 Jan - 5 Feb	Sensitivity Testing of Locations
6 Feb - 12 Feb	Complete Wearable
13 Feb - 19 Feb	Bluetooth Interfacing
20 Feb - 26 Feb	Bluetooth Interfacing
27 Feb - 5 Mar	Spatiotemporal Pattern Design
6 Mar - 12 Mar	GPS app API integration
13 Mar - 19 Mar	GPS app API *& Doc Revision*
20 Mar - 26 Mar	*Department of Computing Exams*
27 Mar - 2 Apr	GPS app API integration
3 Apr - 9 Apr	Application Graphical User Interface
10 Apr - 16 Apr	Application Graphical User Interface
17 Apr - 23 Apr	Application integration and testing
24 Apr - 30 Apr	Preparation for Imperial Festival
1 May - 7 May	Preparation for Imperial Festival
8 May - 14 May	User Testing
15 May - 21 May	User Testing
22 May - 28 May	Report Writing and User Testing
29 May - 4 Jun	Report Writing
5 Jun - 11 Jun	Report Writing
12 Jun - 18 Jun	Report Writing
19 Jun - 25 Jun	Report Writing
26 Jun - 2 Jul	Presentation

The plan shown in table 1 shows the proposed completion of the wearable by 12^{th} February before moving on to the implementation of the mobile phone application starting with the integration of the Bluetooth communication between the phone and the microcontroller and the design of the spatiotemporally encoded pattern messages to be transmitted. Three weeks have been allocated for this work which leaves ample time to investigate the different ways in which it is best to implement between Android and HTML5. Should this work be completed early the plan would be brought forward to allow more time to be spent on the other parts of the application.

During the investigation and implementation of the external GPS navigation app API there will be an unavoidable disruption due to timetabled exams in the Department of Computing. However the 3 weeks assigned for this should again prove an adequate amount of time before moving on to the application design and the GUI implementation for which 3 weeks have been assigned due to unfamiliarity with GUI implementation.

There is a possibility that the project may get the opportunity to be demonstrated at Imperial Festival. If the project is chosen to appear at the festival then time will need to be allowed for preparation of an appropriate version of the product to demonstrate, providing the opportunity to collect some valuable test data from a variety of test subjects and to gain insight into peoples' ideas and perceptions of the device. Should the project not be chosen to appear at the festival the plan will be brought forward by 2 weeks to allow more time for user-based testing.

The remainder of the plan is dedicated to bringing the product together and testing on users to collect data and evaluate the project with the final number of weeks dedicated to the writing of the final report.

In the case that problems arising during implementation resulting in decreasing time spent on the later stages of the project there will be a focus on completing the wearable part of the project and ensuring that it is independent of the application, enabling multiple applications to be designed to run on it. In this case the application that is to run on the mobile phone can be simplified or changed to take less time to produce to still enable testing of the product.

Similarly, if the project is finished well within the available timeframe the application could be extended to include further functionality or an additional application could be produced.

5 Evaluation

5.1 Location Sensitivity Testing

An experiment is required in order to determine the best location for the vibratory motors to be placed from the suitable sites identified in the paper "Assessing the Wearability of Wearable Computers" [25]. This test will be carried out on a number of volunteers who will have a small array of vibratory motors applied to the skin of the lower back, shoulders, neck and the backs of the hands in turn. A small selection of vibration patterns will be performed by the motor array, for each location and vibration pattern the test subject's correct interpretation will be measured. On the completion of the test in each site, the test subject will be asked to rate how comfortable and understandable the vibrations were in each location and whether having the array of motors in that location would be an annoyance or get in the way of everyday activities. Once this experiment has been carried out, and identified the most suitable location, the creation of the wearable can be completed.

5.2 Pattern Design Testing

On completion of the wearable and the Bluetooth communication setup, each of the vibration patterns to relay instructions must be tested to ensure that they are intuitive to the wearer. In this test a large variety of different spatiotemporally encoded patterns will be run on the wearable from the mobile phone, some of them being the designed instruction patterns and some without planned meaning, and the test subject will be asked to identify the meaning of each pattern. The subject will have had no training before the experiment and so will have no prior knowledge of the vibration patterns. The ratio of correct interpretation for each of the designed spatiotemporal patterns will be recorded. This test will be used to identify well designed patterns and patterns that require redesigning to become more intuitive.

5.3 Imperial Festival Demonstration

The possibility of presenting the project at Imperial Festival brings the opportunity to test the project idea on members of the public. In this case the product will need to be adjusted as it would not be practical to ask people to wear the wearable in these conditions as it is required to be worn underneath clothing as well as test subjects being a variety of ages and, although it will be designed to fit a variety of different people, the wearable is designed to be worn by adults. Nor would it be suitable to use the GPS navigation application as this would result in time consuming experiments and require leaving the Imperial Festival site. For the Festival, arrays of vibratory motors will be embedded in gloves to interact with skin on the backs of the hands, this will allow for easy application and removal of the hardware and gloves allow more size adjustability, it may be suitable to create one set of adult-size gloves and one set of child-size gloves. A new, simple mobile phone application will be created to instruct the wearer to go forwards, backwards, left or right. A volunteer will be asked to wear the gloves and to negotiate a small obstacle course or maze with the help of another volunteer who will have to guide them using the application on the mobile phone. The correctness and speed with which the wearer interprets instructions will be measured and any informal feedback given concerning the product will be recorded. Despite the changes to the design the product used in this experiment is very similar to that which is proposed in this report and these tests will provide data as to whether vibratory motors can be used to give directions and to communicate a new sense through the sense of touch.

5.4 Final Product Experiment

The testing of the final product will take place after Imperial Festival. The final set of experiments will test whether the sense of touch can be used as a channel to communicate a completely new sense to the brain. The test will be broken down into 2 parts. The first will test the level of understanding of information passed via touch that can be achieved using spatiotemporally encoded patterns of vibration. The test subjects wearing the device will be asked to identify instructions given by the vibration patterns to find out how intuitive the instructions are, the correctness and speed at which they answer will be recorded. The second part of the experiment will test whether the test subjects are able to understand a new and unnatural sense being communicate through touch, in this case a sense of direction from GPS navigation. The tests will be conducted with a variety of volunteers who will be set a navigation task in an unfamiliar location, the correctness of their route will be recorded along with their awareness of their surroundings. On completion of the experiment the test subjects will be requested to fill in a questionnaire with questions concerning the comfort and their acceptance of the device, the effort required to understand the information relayed to them, whether they felt more aware of their surroundings compared with using a map on their phone and whether they preferred the device in comparison to a conventional GPS navigation mobile phone application.

6 Conclusion

This report proposes the use of wearable technology to communicate a new sense via the channel of touch. The design outlines the use of vibratory motors controlled by a microcontroller embedded in a piece of clothing and receiving the information to relay to the brain from an application running on a mobile phone. The application proposed for the testing of the wearable is the creation of a sense of direction using GPS navigation. The wearable will be application independent to allow further sense applications to be implemented using the same wearable. The aim of the project is to attempt to supply the opportunity to create completely new senses and to evaluate the possibility of communicating with the brain through one of the lesser used senses.

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