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Navigational Tool for the Blind

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Abstract. Human wayfinding can be thought of to be constituted of two components - obstacle detection and navigation. However, current products for the purpose of mobility for the visually impaired are limited to solutions for obstacle detection. There is a gap that needs to be addressed in the space of navigation. Hence, we propose a two-piece assistive wearable device that fills this purpose in a manner that is intuitive to the user. For this, our choice of feedback was using haptic technology. The feedback will be generated using vibrational motors and will be used to indicate left and right turns and arrivals. A vibration on the corresponding module will indicate that respective turn to be taken while a vibration through both modules will indicate that the destination has been reached. To ensure that all aspects integral to wayfinding are covered, a buzzer is included on the device that will beep when there is an obstacle in the user's path. Hence, we propose an intuitive mobility aid based on certain intent and their corresponding mapping.

INTRODUCTION

Navigation for the visually impaired has been an active subject of research for decades. When it comes to navigation for the blind, it is crucial to understand their needs, mainly being the understanding of their surrounding environments beforehand, intimating them about navigational directions without encumbering their primary senses and on time continuous guidance. With respect to the current scenario of navigation for the blind, they tend to rely on a guide or strangers for directions or restrict themselves from travelling to unfamiliar places. Most products mainly focus on obstacle detection or most blind users due to lack of options stick to the conventional white cane. Between the various programs and schemes available for improving their independent functioning and products for obstacle detection, there is a gap that needs to be addressed in the space of navigation. We propose a two-piece wearable that fills this purpose. The model works by generating haptic feedback using vibration motors. The following functions may be performed:

- A vibration on the left module will notify the user of an upcoming left turn.
- A vibration on the right module will notify the user of an upcoming right turn.
- A vibration on both modules will indicate that the destination has been reached.

Additionally, we have a feature that helps with obstacle detection that can be attached to the white cane - a tool most visually impaired are comfortable using, which warns the user if there is an obstacle 5 feet ahead of them via a buzzing sound. This is done using an ultrasonic sensor and a piezo buzzer. This functionality helps with better intuition with respect to navigation when combined with the haptic response of the wearable device. Assistive devices [1] provide plausible aids for people disabilities, particularly the blind. Devices worn on several parts of your body such as hands, head, tongue, feet etc., have been proposed earlier to create wearable solutions for mobility. Hearing and touch act as major senses, for the blind. They help gather information from their surroundings for daily activities. However, some particulars must be taken into consideration:

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1. Overload of senses
2. Adaptation time
3. Acoustic feedback
4. Tactile feedback

LITERATURE REVIEW

A navigational and obstacle detection wearable device is proposed by Jinqiang Bai, Shiguo Lian, Zhaoxiang Liu, Kai Wang, Dijun Liu [2]. It is a novel device that tries to solve the obstacle detection problem. Additionally, a hands-free, intuitive and inconspicuous wearable device is proposed that allows visually impaired users to detect above and below knee height obstacles in the user's immediate surrounding [3]. M. Sreelakshmi, T. D. Subash [4] discusses the immense potential haptic has to bring about change in the communication field and the various kinds of interfaces that makes it a viable option for convenient navigation. Four haptic feedback-based prototypes were proposed for pedestrian navigation by Ricky Jacob, Peter Mooney, and Adam C Winstanley [5] .The proposed method requires the user to point a device at different directions in order to be intimated of the shortest/right direction to their destination. Azenkot et al [6]. Talk about three ways of using vibrations on your smart-phone to provide directions. A paper by P. Costa, H. Fernandes, J. Barroso, H. Paredes and L. J. Hadjileontiadis [7] was focused mainly on obstacle detection and avoidance using novel methods such as the Computer Vision module of the Navigator prototype.

Motivation and contribution

The motivation was to bridge the gap of navigation and help the blind to be more independent. Most visually impaired individuals are dependent on someone else for their mobility. The blind community is confined to their homes due to lack of mobility options. According to a report - Global Data on Visual Impairment by World Health Organization, there are over 200 million people suffering from moderate to severe vision impairment in 188 countries. This number can be expected to increase to 550 million by 2050.

Human wayfinding can be thought to be constituted of two primary components: sensing of the immediate environment for obstacles and hazards which might hinder travel and navigating to locations outside the immediate surroundings [8]. It is a goal-oriented process and relies heavily on cues from the adjacent surroundings in order to be rendered successful. These cues, most predominantly tend to be visual observations - obstacles, signage and landmarks, along the chosen route to the destination. This is where the visually impaired are at a significant disadvantage. They fail to pick up on these visual cues and hence lack the necessary information required to help orient them- selves along the required route while traversing through an unfamiliar environment.

METHODOLOGY

Through this project, we hope to substitute the lack of visual cues through other intuitive means. Certain aspects were taken into consideration to ensure that the assistive aid devised-

1. Does not hamper the normal functioning of the body
2. Does not cause further distractions
3. Is able to be used intuitively
4. Is discrete in design and appearance

Table 1 represents the Components and their use in the model. Hence, we propose a two-piece shoe attachable device that provides real-time turn by turn navigation by use of haptic feedback. The system can be thought of two be composed of two major components:

The wearable device and the smart phone application. Table 2 shows the intents and their corresponding mappings.

TABLE 1. Components and their use in the Model

Component	Purpose
Arduino Nano	Microcontroller Unit (MCU)
HC-05 Bluetooth Master-Slave Transceiver	Bluetooth Transceiver for facilitating communication between the MCU and the user's mobile device.
NRF24L01 Radio Frequency Transceiver	Radio Frequency Transceiver for facilitating communication between the two MCUs.
HC-SR05 Ultrasonic sensor	Used for estimating distance between user and oncoming obstacle.
Vibration Motor	Used for generating haptic feedback

Wearable device

The wearable device would consist of two ergonomically optimized attachable. One would behave as the master node and the second would be the slave. Figure 1. shows the working of right navigation and Figure 2. shows the working of left navigation model with prompt from the application. The master node is composed of the following units:

TABLE 2. Intents and their corresponding Mapping

Intent	Mapping
Left Turn	Vibration felt through the left module.
Right Turn	Vibration felt through the right module.
Arrival	Vibration felt through both modules.
Wrong turn	Vigorous vibrations felt until the user reorient themselves along the correct direction.

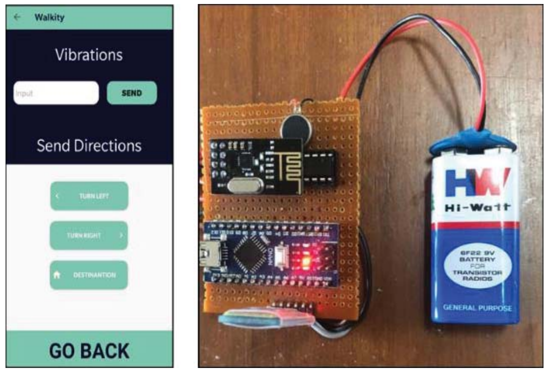


FIGURE 1. Working of the right navigation model with a prompt from the application.

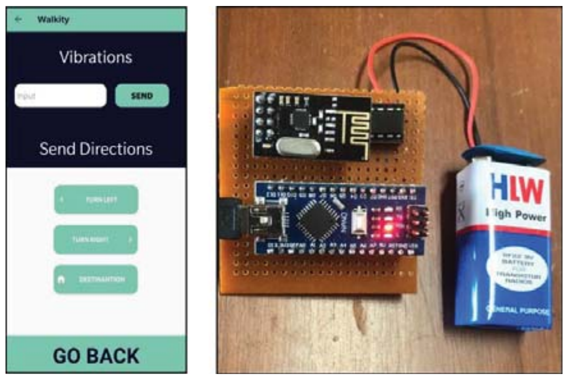


FIGURE 2. Working of the left navigation model with a prompt from the application.

When the user wishes to commence their journey, they may initiate pairing between the mobile device and the MCU. Figure 3. Shows the Application screen with user interface and Figure 4. shows the flow of operation of Navigation Device.When a connection is established between the two, a beep is heard to notify the wearer to initiate the next step. Now, the user can feed in their destination into the application by means of audio input. By the STT capabilities available on the mobile phone, the audio request is fed into the application as text. Figure 5a. represents the architecture of model for navigation and Figure 5b. shows the architecture of model for obstacle.

The HC-05 module relays the information prompts from the application to the MCU in the master node and a mapping takes place to resolve which motor is to vibrate. Should the prompt be that for an upcoming right turn, then the MCU in the master node causes feedback to be generated via its respective vibrational motor. Should the prompt be that for an upcoming left turn, then the MCU in the master node transmits the request to the MCU in the slave node through the connected Radio Frequency (RF) transceiver.

Upon receiving the prompt from its own RF receiver, the MCU in the slave node confirms that the information passed is the instruction to generate feedback through its vibrational motor and does so causing a vibration to be felt through the left vibrational motor. In this manner, the user traverses through the recommended route to their destination, reorienting themselves when necessary based on the haptic feedback received through the vibrational motors. Should the user arrive at their destination, a vibration is felt through both devices to indicate so. Thus, through a series of intents and their corresponding mapping, the user is provided with turn-by-turn navigation to their destination. Figure 6a. Shows the operation of right navigation model and Figure 6b. Shows the operation of left navigation model.

Obstacle avoidance device

The Ultrasonic sensor is activated/prompted at regular intervals. The Sensor transits 8 ultrasonic/acoustic wave bursts and initiates the time counter. If an obstacle is present, a wave is reflected back to the sensor and the timer stops when the received echo is picked up by the sensor. Time difference is used to calculate the distance, if the distance is < 5.5ft, the buzzer makes a sound. If no obstacle is present, the counter times out and the whole process is initiated again. Figure 7. Shows the operation of Obstacle Avoidance device.

We calculate the distance as follows:

Distance (cm) = 17150 * Time(s)

Application

The application is built using Android Studio in Java with the help of the Google Maps Directions API and Google Speech to Text API. To make it accessible to individuals with visual impairment or low vision, we have made sure that the following factors were taken into consideration during the design of the application:

1. Use of large text
2. Use of alt text for images
3. Use of contrasting colours - green blue
4. Use of textures
5. Use of dark mode
6. Minimalism

User launches the application and receives a prompt to connect their smartphone to the wearable device. After pairing, users can speak in their destination. Using Google Speech API, this spoken destination phrase is converted to text via Speech-To-Text using the Synchronous Recognition method. This converted text phrase is added in the destination parameter of the Directions API call. The origin parameter is filled using the user's current geographical coordinates using the smartphone's GPS and internet connection.

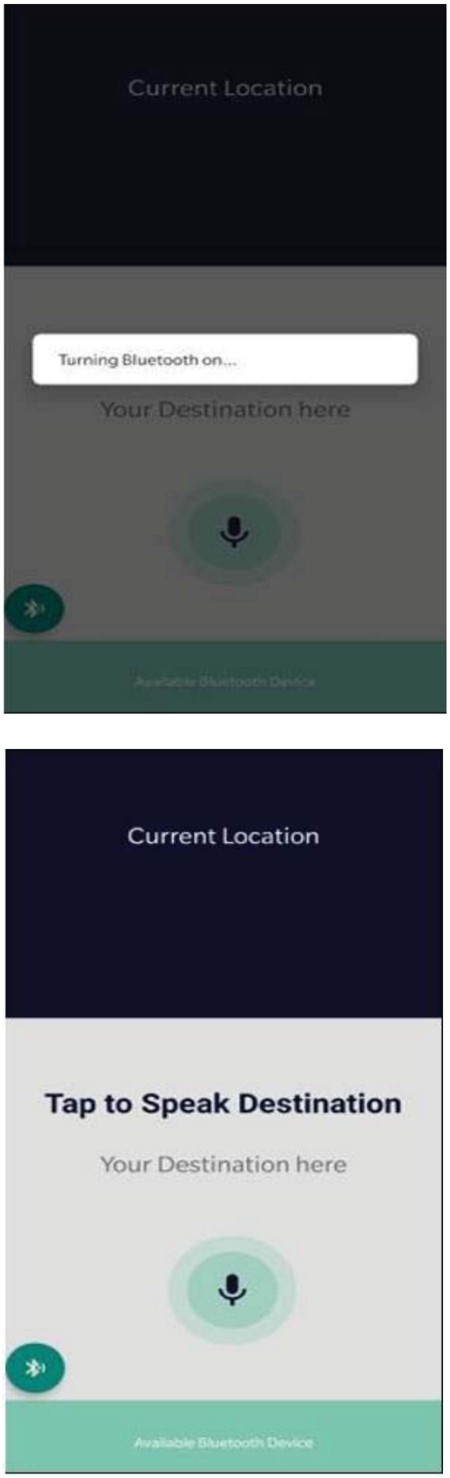


FIGURE 3. Application Screen of User Interface

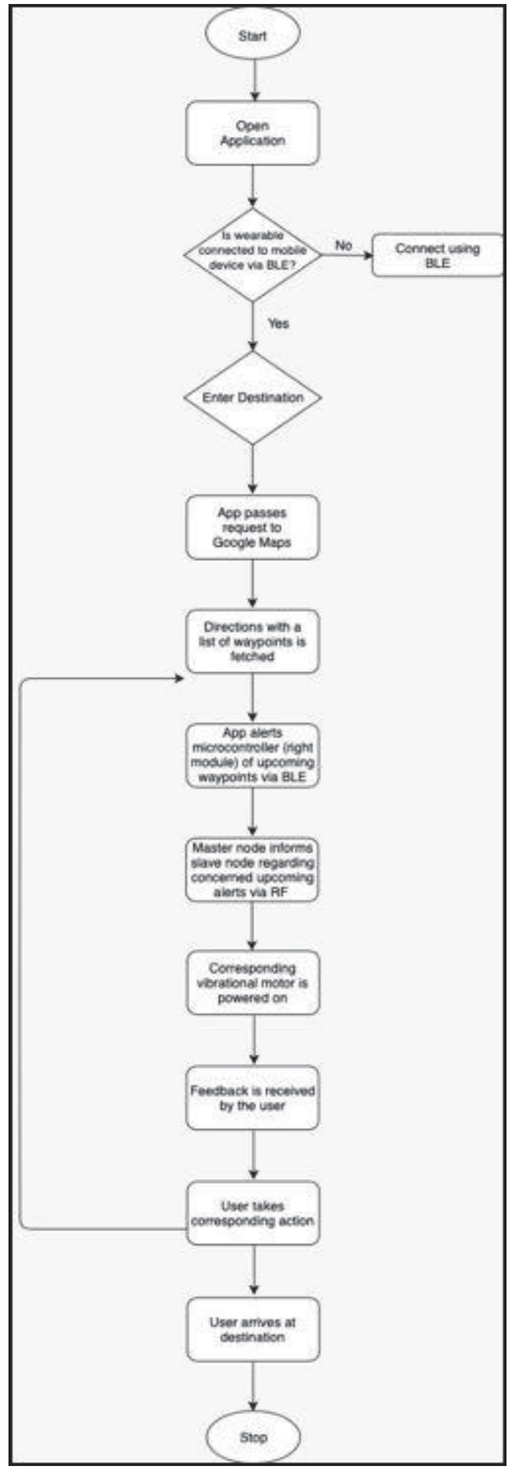
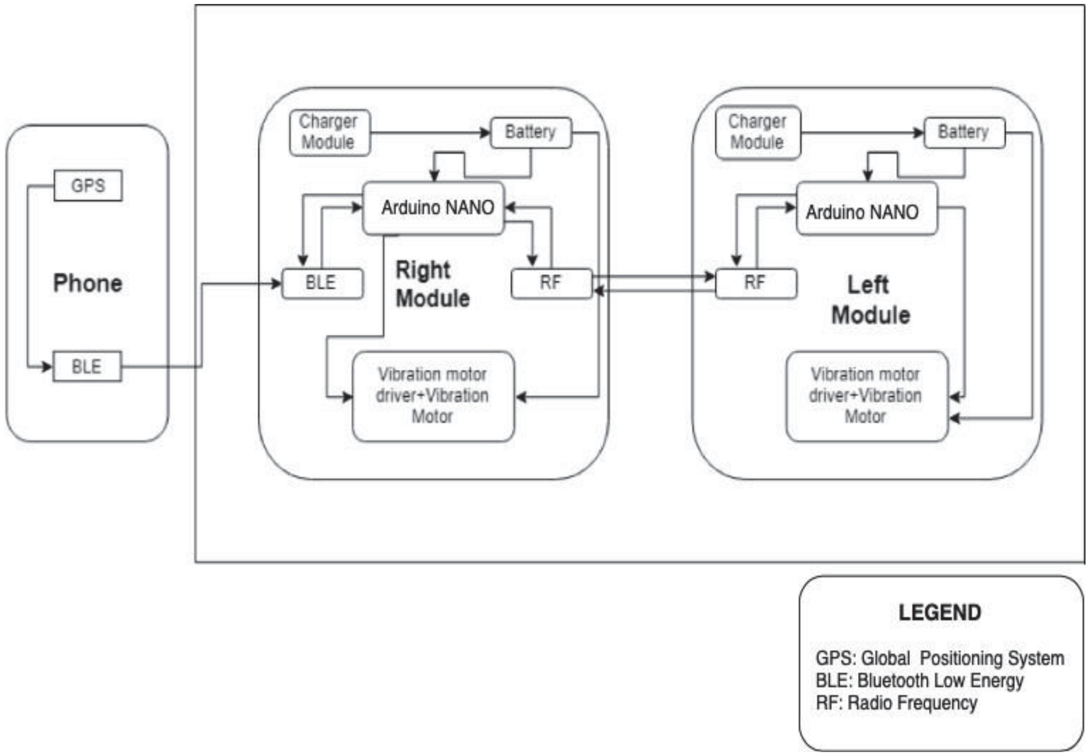
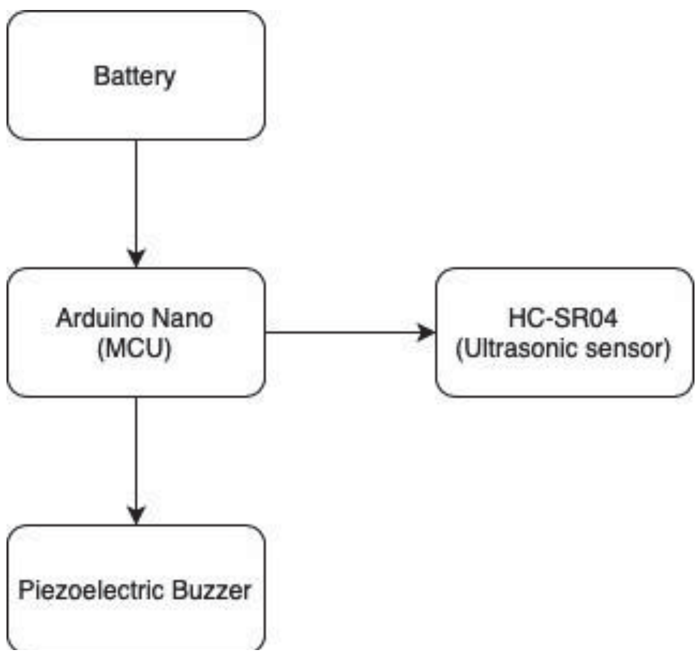


FIGURE 4. Flow of Operation

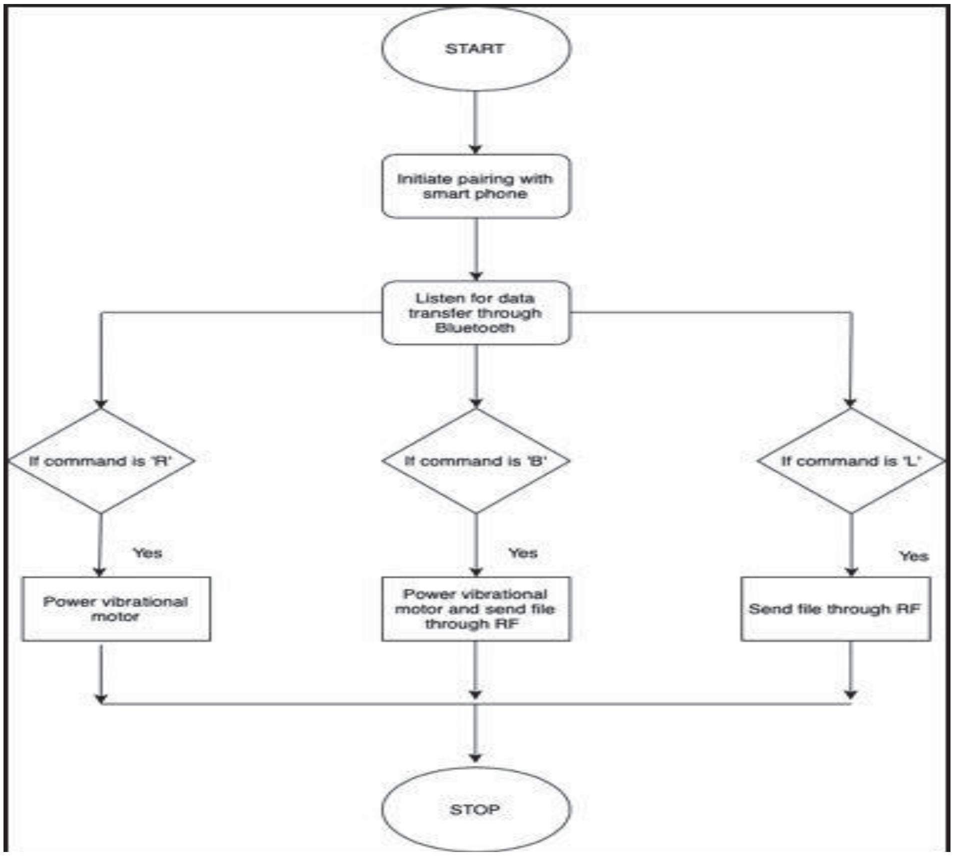


(a)



(b)

FIGURE 5. (a) System architecture of model for navigation (b) System architecture of model for obstacle avoidance



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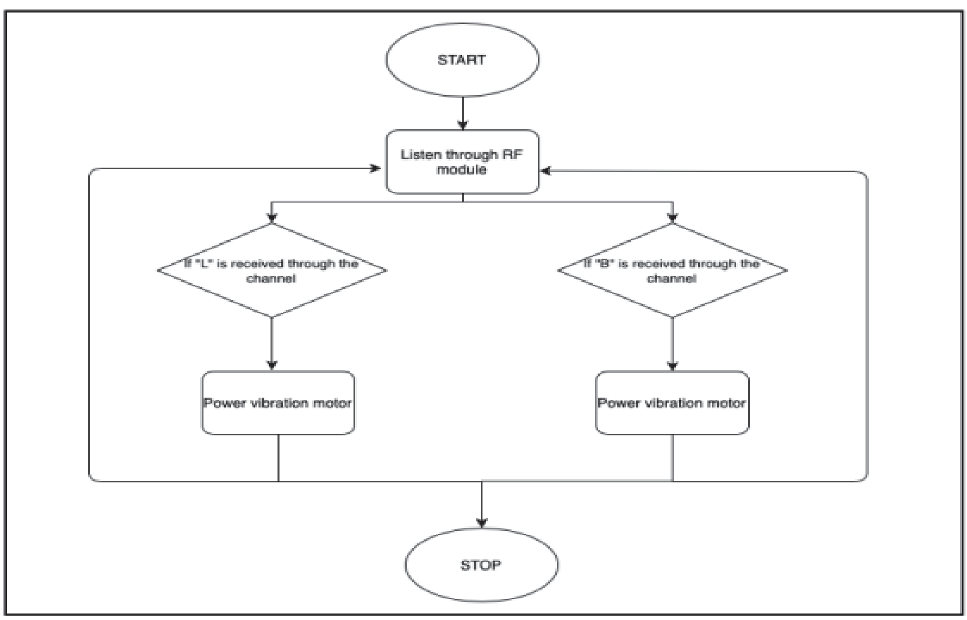

(b)

FIGURE 6. (a) Flow of Operation of Right Navigational Model (b) Flow of Left Navigational Model

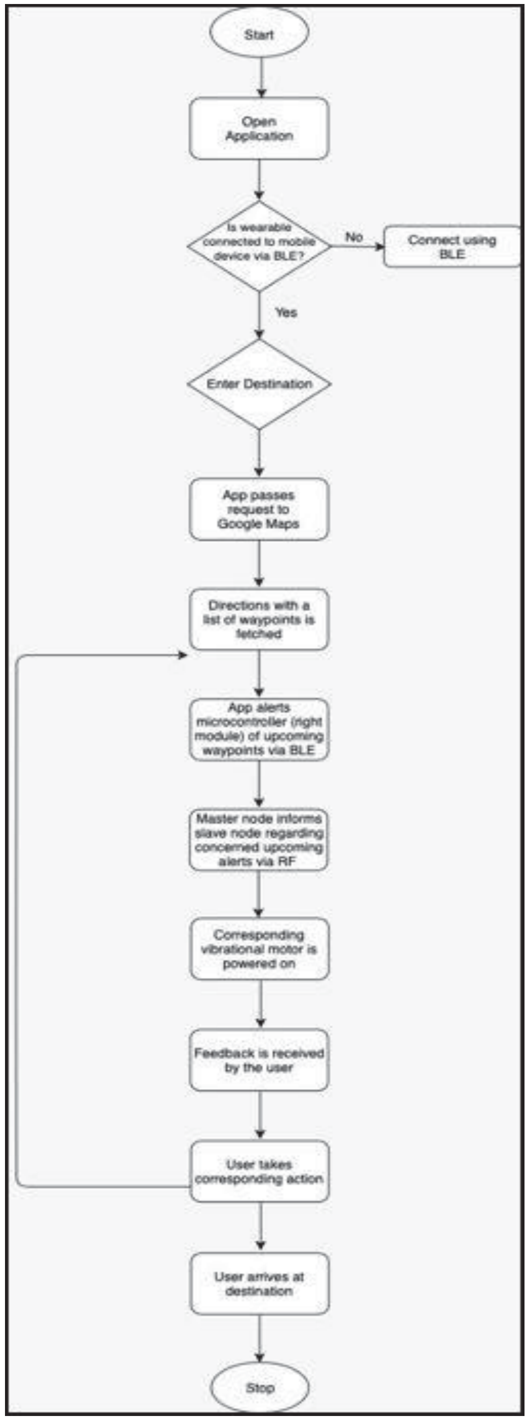

FIGURE 7. Flow of Operation of Obstacle Avoidance Device

RESULT

Our model provides a twofold solution for the problem of human wayfinding by providing a solution for navigation as well as obstacle avoidance. The navigational aid consists of a pair of leg attachables that provide haptic prompts in order to inform the user of the direction and instance of an upcoming turn or waypoint while the obstacle avoidance model enlists the use of sound navigation ranging (sonar) in order to estimate the presence of an obstacle along the user's path. The criteria for the evaluation of navigational aids, as put forward by armstrong, suggest that the aid ensures the safety of the user, is efficient and does not cause additional stress while being used.[9] by these standards, we validate our model by proposing an experiment conducted by martinez et al[10] wherein a comparison study was conducted between the cognitive load imposed by haptic and audio feedback for the purpose of short navigational tasks. To represent the contesting modalities, in lab audio and haptic interfaces were used on a sample of six white cane users. The users were evaluated using the nasa-tlx (task load index) protocol to discern the workload of each modality. It was found that the workload induced by a phonic system was rated at 74.7% - 23.3% of this was caused from user frustration and 6.6% came from their performance as opposed to a workload of 3.3% while haptics were used. Figure 8.shows the nasa task load index for navigation experiment.

Thus although both modalities are competent contenders for the purpose of feedback, it was proven that the cognitive load of audio feedback is upto 22 times than that of a haptic based feedback system. We propose that our model will encourage their independent functioning in the space of mobility and orientation (o&m) by alleviating some of the restrictions imposed on a visually impaired individual during travel related tasks and giving those who never leave their homes alone [11][12][13] some confidence to execute their travel related tasks.

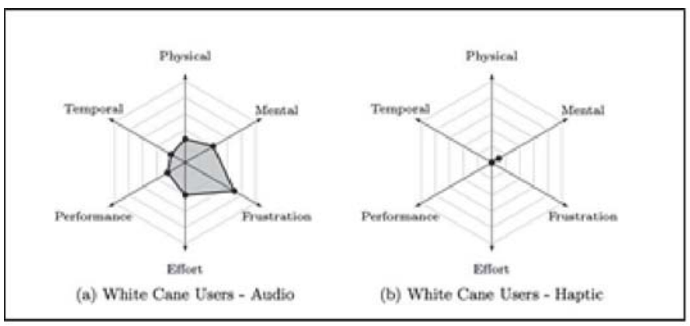

FIGURE 8. Nasa Task Load Index: Sources of Workload For The Short Range Navigation Experiment [14]

Currently, these individuals memorise lengthy list of directions in detail [15] and re- quire to focus their efforts on construing their immediate geospatial whereabouts and the various moving components.Figure 9. shows the hardware for navigation modules that can be fashioned into wearable for all body sites, and Figure 10. shows the hardware attachable to enhance the functionality of the white cane.Providing them with a gis based system will eliminate the need to perform such an ar- duous task and also solves issues stemming from the removal/movement of temporary localised landmarks or position markers set by individual persons by replacing them with global landmarks.[16] Furthermore, according to an experiment conducted by kammoun et al[17]to evaluate the detection of a haptic prompt across various body sites, it was found that feed- back given directly to a body site such as hand, wrist etc had a 100% detection rate as opposed to those given via an intermediate medium such as pockets as the latter is dependent on the fabric and specifications of the type of cloth used.

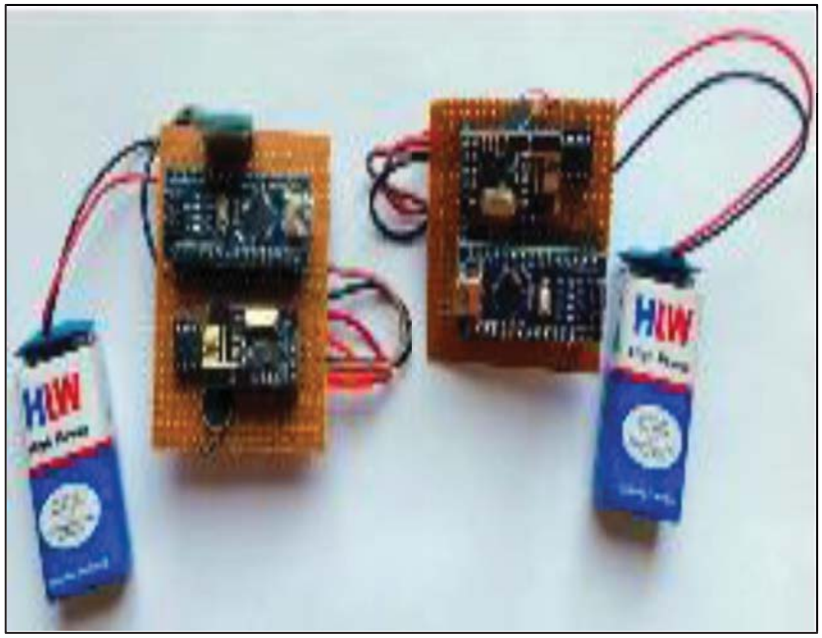

FIGURE 9. Hardware for the navigational modules that can be fashioned into a wearable for all body sites

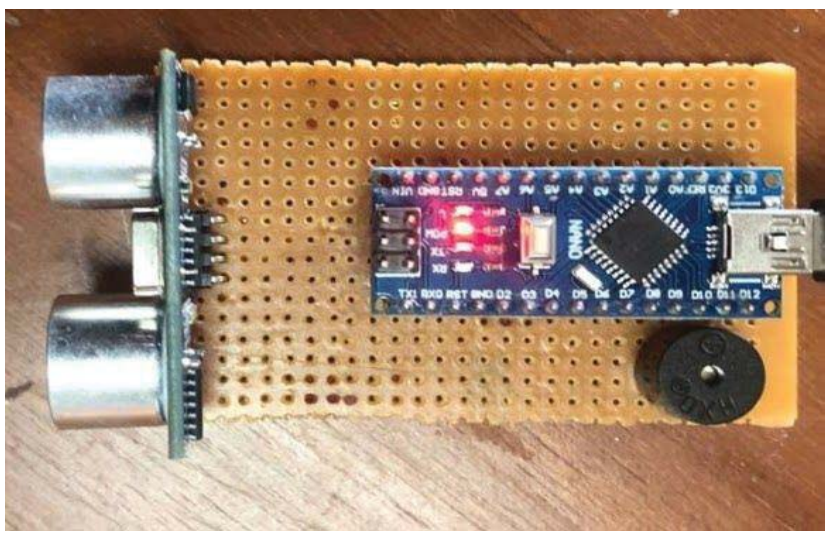

FIGURE 10. Hardware attachable to enhance the functionality of the white cane

CONCLUSIONS

Thus, a pair of wearable devices and a supplement for the white cane is constructed in order to aid visually impaired individuals with both aspects of human wayfinding, i.e., obstacle detection as well as navigation. The prompts for alerting the user of their immediate surroundings were provided through an alternate modality,i.e, haptics, in order to reduce cognitive overload and allow them to be fully cognizant of their surroundings. We have also taken into con- sideration body sites where prompts are easily detected and hence settled on a wrist/leg attachable. In order to enhance functionality of the existing white cane, we propose a cane attach- able that uses the principles of sonar in order to let the user know of the presence of obstacles in their path. Care was taken to ensure that the feedback is adjusted to provide an intuitive, distraction-free experience for the wearer and will hence encourage their independent functioning in the space of mobility and orientation (o&m).Future efforts should be focused on improving the accuracy of the maps service providers and exploring indoor environments in order to provide a comprehensive solution to the problem of wayfinding.

Future enhancements

Haptic feedback may be used to provide solutions for other fields of study due to its intuitive, hands free experience. This allows us to provide solutions for indoor navigation as well through concepts such as dead reckoning and simultaneous localization mapping (slam). Dead reckoning is a relative navigation method that calculates the path length starting from a known position and successively adding displacements. [18] [19]. Another alternative positioning solution - slam creates a local visual map of a de- fined area by working a mono-vision camera across the environment and putting the result through an image processing system. Haptic feedback technology aids the recognition of location markers and their adjustments to improve system efficacy and reduce runtime errors. These positioning technologies are very crucial to location-based services, some of which require real time responses. A safety feature that allows the user to return back to a saved location even when offline through the use of breadcrumbs is also a key application.[20] This can be improved by intelligent suggestions using route optimization algorithms based on authentic crowd sourced data.[21] this technology, i.e., haptics, helps provide real time coordination between artists, players and performers. Haptic feedback helps cyclists, two-wheeler riders and marathon enthusiasts to navigate without looking at their phones. It can also play a role in the smart tourism industry as tourists can be benefited by using haptic feedback in order to avoid looking at their phones constantly while navigating through unfamiliar places.

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