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System for Visually Disabled through Wearables Utilizing Arduino and Ultrasound

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Abstract

Blindness and other vision impairment is on the rise with more than 2.2 billion people worldwide are affected including children, elder persons, pregnant women, chronically ill and disabled persons who experience difficulties in mobility and being independent. Some of the conventional assistances like usage of white cane or a guide dog lacks the ability to cater all the needs of the blind people. The present research outlines a wearable system with Arduino and ultrasound equipment to improve the walking ability of the persons with vision impairment. From the use of the proposed system, there is the potentiality of detecting obstacles in real time and also determine the location hence minimizing the dependence on other help. The system consists of two wearable components: a glove and a belt which contain ultrasonic sensors, GPS module and GSM module and a vibration motor. The glove senses the objects that are in front of the user while the belt detects stairs or any other raised ground. The method used here was the development and calibration of these components separately then brought together to form a coherent entire system where all the component was precise and reliable. The findings show that the proposed system is successful to identify obstacles on its path before the user comes close to them and gives out alerts through sound and touch. GPS and GSM modules provide an extra layer of security to the kids by allowing a tracking of their location in real time.

Introduction

Vision is an essential sense for interacting with the surrounding environment effectively (Kuriakose et al., 2022), according to the World Health Organization (WHO), fact sheets released in 2021 peop, over 2.2 billion individuals globally experience visual impairments, encompassing both blindness and vision challenges. Individuals who experience visual impairment are commonly referred as individuals with blindness (Pashmdarfard et al., 2016). Worldwide, there is a concerning statistic: every 5 seconds, one individual becomes visually impaired, and every minute, one child experiences visual impairment (Senjam et al., 2021). Enhancing the quality of life for visually impaired and blind individuals is significantly influenced by the progress of technologies. Innovations and research in this domain predominantly focus on creating wearable assistive devices tailored to the unique requirements of those with visual challenges (Lay-Ekuakille & Mukhopadhyay, 2010). There are several problems suffered by blind people beginning from indoor activities such as freely

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walking in their house down to outside activities execution by freely walking on the roads. Today, due to the technology's advancement, several software programs are being progressed and embed on electronic tools such as mobiles and computers to assistance the blind people. The advanced systems using deep learning and Artificial Intelligence help the researchers to evolve aids that enable the blind people to accomplish all their activities with comfort like helper aid for walking, portable and easy to use pen, writing aid with low cost for blind and visually impaired people (Kuriakose et al., 2022; Juneja & Joshi, 2020). In the past, individuals have relied on conventional navigational aids like white canes and guide dogs, which are currently the most widely used assistance methods (Fei et al., 2017). However, these devices have limitations and can only provide limited navigation information. To address given these limitations, an increasing demand arises for an additional system, method, tool, or compact, portable technology. In recent years' Considerable advancements have been made in the evolution of technologies aimed at assisting visual needs (VATs). Which are categorized as visual improvement, visual replacement, or visual substitution based on their utilization of electronic devices and sensor functions (Darabont et al., 2020). China has a population of approximately 13 million individuals with visual disabilities, of which over 8 million are reported to be blind (Jing et al., 2023). Although specific figures regarding the population with visual impairments in Iran are not available, estimates suggest that the occurrence of visual impairment ranges from 1.2% to 4.2% for low vision and 0.7% to 1.3% for blindness in different parts of the nation (Katibeh et al., 2015; Mohammadi et al., 2017). The need for miniaturized and wearable sensors has experienced a significant surge. Because there is a particularly high demand for novel sensors designed for wearable medical devices (Trovato et al., 2022).

It appears that the authors Elmannai & Elleithy (2017) conducted a comprehensive survey comparing portable and wearable assistive devices designed for individuals with visual impairments. They thoroughly examined the functionality and usage of these systems, shedding light on crucial aspects. By presenting this information, they aim to assist other researchers in developing and implementing devices that ensure the safety, security, and enhanced mobility of visually impaired individuals.

They organized the systems into different categories according to the type of sensors used, level of accuracy, analysis type (online, offline, real-time, not-real-time), indoor/outdoor coverage, measuring angle, cost, limitations, day/night functionality, maximum/minimum object detection range, and classification of objects as dynamic or static. Additionally, they took into account the techniques employed for detection, recognition, or localization. The authors speculated that the majority of existing technological solutions for individuals with visual impairments address specific aspects of the problem. They classified these solutions into two distinct classes: (1) Obstacle detection systems: These systems focus on sensor technology, information conveyed, user interface, type (handled or cane mountable), price, and any special features they may offer; (2) Navigation systems: These systems primarily deal with facilitating navigation for visually impaired individuals (Chanana et al., 2017).

The authors Ganguli et al. (2016) of the study in 2016 provide a comprehensive overview of the noteworthy research conducted in the field of assisting visually impaired individuals, starting from traditional handheld white canes to the development of smart sticks with various programming enhancements. They present a timeline table featuring Smart Sticks from 1966 to 2015, categorizing these devices based on Electronic Travel Aids, manufacturers, and their intended usage. The author's proposed methodology aims to develop an object detection system for blind individuals and those with visual impairments. The edge box algorithm was used as an intelligent and safe approach to process each image within a frame. When getting a positive response from an object, the system utilizes audio alerts to warn users. The assessing of the results was evaluating using the metric of mean average precision (MAP),

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and it detected lower complexity and higher accuracy compared to the faster R-CNN (Wong et al., 2019).

The authors suggested a system designed to help blind individuals in calculating distances and revealing obstacles along their path. They employed YOLOv2 to train the system, assisting it to determine the distance, create image descriptions and assess the person's length and to provide audio response to the user. They combined data from an ultrasonic sensor mounted on the Arduino Uno with the output of the object detector. By using the deep neural network previously tested, The system successfully revealed objects with an accuracy of 97%. While other methods that only revealed the obstacles presence. The suggested approach could specify several object classes and estimate depth with accuracy (Shahira et al., 2019).

The GPS device locates the blind individual in an instant and sends the coordinates to the GSM system. The recipient then receives an alert message with the blind person's location. In addition, voice recognition gives information about the distance of impending barriers, and ultrasonic sensors are employed to detect impediments. Moreover, the stick's functions are unlocked by a fingerprint scanner, allowing access to only those who are permitted. Nonetheless, there's still a chance that unapproved users will take advantage of this technology (Gurubaran & Ramalingam, 2014). In Ramadhan (2018) Create a smart wearable solution to assist those with visual impairment in navigating streets and public places while requesting assistance. A microcontroller board, an array of sensors, cellular connectivity, GPS modules, and a solar panel are among the essential components of the system. These sensors are used to track the journey and advise the user of impending hazards. Notifications are sent using a combination of auditory and haptic vibrations on the wrist. in Sen et al. (2018) introduced a blind stick with an ultrasonic proximity sensor and a GPS module with configurable sensitivity.

NavGuide Patil et al. (2018) recognized impediments and evaluated the surrounding environment using ultrasonic sensors. The system may provide basic information to the user to identify various impediments, such as damp surfaces, objects at ground level, and those that are knee-high, by using vibrating and audible alarms. However, if it does not detect potholes or slope paths, it has limits. Wet floors can only be detected when the user steps on them. In the study described in reference Marzec & Kos (2019), a system was presented that makes use of infrared sensors to identify various items such as structures or barriers. This system is designed to be worn on the user's arms and sends out navigational cues using vibrations. These vibrations communicate details about steps for movement and possible obstacles in the vicinity.

In this research Islam et al. (2018), a navigation system was proposed, utilizing cost-effective components like Arduino Nano, Arduino Pro Mini, IR transmitters, IR receivers, and headphones, which are readily available and easily interfaced. However, the design has some limitations that require further improvement. The number of IR transmitters depends on the room size, and a large indoor area may necessitate a considerable number of transmitters.

The authors Kher Chaitrali et al. (2015). have proposed a navigation aid specifically designed for visually impaired individuals. The device focuses on utilizing infrared sensors and RFID technology, along with Android devices, to provide voice output for obstacle detection and navigation. It aims to assist partially sighted or blind individuals in traveling with confidence and ease, similar to sighted people. The device incorporates proximity infrared sensors and RFID tags, which are placed in public buildings and integrated into the user's walking stick. It is intended to be compact and used in conjunction with the white cane. The navigation device connects to an Android phone via Bluetooth and relies on a dedicated Android application. This application provides voice-guided navigation based on the data from the read RFID tags, and it also updates the user's location information on a server. Additionally,

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another application allows family members to access the blind person's location information through the server whenever necessary.

The research Nalavade et al. (2014) aimed to develop a system for detecting obstacles using ultrasonic sensors. Additionally, it incorporates GPS technology to provide accurate location details, which are then sent via SMS to the user's relatives. In Guimarães et al. (2013), an alternative system employed sophisticated sensors is discussed, wherein ultrasonic sensors and a GPS system are integrated into a white cane to determine the user's position. The proposed system comprises a foldable stick equipped with two IR sensors. These sensors are integrated with an earphone using ISD1932 flash memory to transmit warning messages whenever obstacles are detected, ensuring the blind person is alerted. The horizontal sensor effectively detects high-level obstacles, while the inclined sensor is capable of identifying stairs and low-level obstacles. The system underwent practical testing, and the feedback received was positive, demonstrating obstacle avoidance accuracy ranging from 75% to 90% (Nada et al., 2015).

The authors Farooq et al. (2022) introduced an intelligent stick equipped with an ultrasonic sensor capable of detecting obstacles in four directions: front, left, right, and bottom. This feature allows blind individuals to avoid puddles using ultrasonic waves. When an obstacle is detected, a motor vibration is activated. The smart stick is enhanced with a combination of ultrasonic sensors, GPS, and GSM-based navigation and tracking system. It efficiently detects obstacles within a 4-meter range in just 39 milliseconds and sends a message to prompt the blind user to move at twice their normal speed.

The authors conducted a comprehensive review of wearable systems designed to assist visually impaired individuals in their daily outdoor movements. They offer consumers a thorough overview of the capabilities of each system, highlighting the notable advantages and restrictions of each technology. These systems have been categorized using a variety of performance criteria that offer both qualitative and quantitative measurements for assessment (Tapu et al., 2014). In Kim (2024) examines previously produced electronic travel aids (ETAs) in depth, focusing on two major factors: the technologies used, and the functions performed. The report offers prospective future research avenues for technological progress in ETA systems for indoor navigation, specifically addressing aid to individuals who are blind or visually impaired (BVIP) based on the findings of this review.

The authors created a wearable helmet-shaped assistive device that improves navigation by using cognitive-based strategies to help visually impaired people locate items in familiar and new indoor surroundings. To boost navigation efficiency, the system employs Object Relations Prior Knowledge (ORPK). They propose employing knowledge graphs and scene graphs to analyse ORPK of unlabelled photos (Hou et al., 2022). In Rathod et al. (2020), an innovative smart wearable technology specifically built for visually challenged persons was demonstrated, allowing for barrier-free travel in both indoor and outdoor situations. It employs simple ultrasonic sensors known for their compact size, light weight, and low power consumption. Although the gadget responds quickly, it should be noted that it may fail to identify items at ground level. A different study suggested combining GPS location monitoring, obstacle and water detection, and other features to assist visually impaired people (Nazri et al., 2021).

Methods

This section outlines the system's parts and tools as well as explain how it operates. An Arduino microcontroller, such as an Arduino Nano or Arduino Uno, and two ultrasonic sensors are needed for the system; one is used to identify obstacles directly in front of a person, while the other is used to recognize obstacles at a lower level, like gaps or holes. Furthermore, required are a DC motor, switch, PIR sensor, battery, GPS module, GSM module, and sound

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output (buzzer). There are two components to the suggested system. The first part is a palm worn in the hand (glove) as shown in Figure. 1.1 and consists of Arduino Nano, Arduino UNO, Ultrasonic Sensor, PIR Sensor, GPS Module, GSM Module, DC Motor, Buzzer, Battery and Switch.

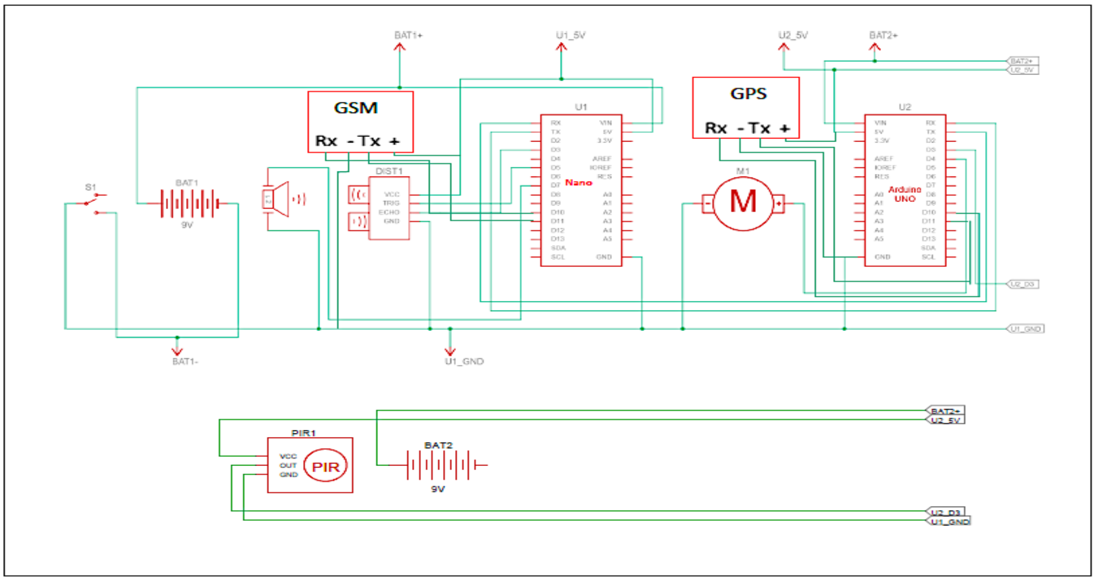

Figure 1. The glove circuit diagram

The second part is a belt as shown in Fig. 2. That is worn around the waist and consists of an Arduino Nano, an ultrasonic sensor, a buzzer, a DC motor, a battery, and a switch.

System Design

Initially, all components and devices of the proposed system were thoroughly tested and verified to be in proper working order. Subsequently, each unit was connected and integrated separately with the microcontroller panel and programmed according to the specific needs and requirements.

The testing process of the system was conducted incrementally rather than testing it as a whole upon completion. Each unit of the system was individually tested, and the second unit was tested only after the first unit yielded the expected results and functioned correctly. Once all modules were confirmed to be working properly, they were integrated to form the complete system, which was then thoroughly tested. This approach allowed for easy identification of any bugs or issues since the behaviour of each unit was known during its individual testing. If the system had been developed and tested as a whole after completion, it would have been difficult to pinpoint problems and errors. After the hardware modules were tested, the connection between the mobile station and the GSM module was examined.

We begin by setting up the development environment on the computer to write the code for our system. Once we confirm that the connection between the mobile station and the module is functioning as intended, we proceed to attach the sensors to the microcontroller and capture the results for analysis using a terminal program. After ensuring that all hardware and software components are properly integrated and the sensors are functioning correctly, we develop the entire system. Following this, we initiate calls to the GSM unit to send the location of the visually impaired person.

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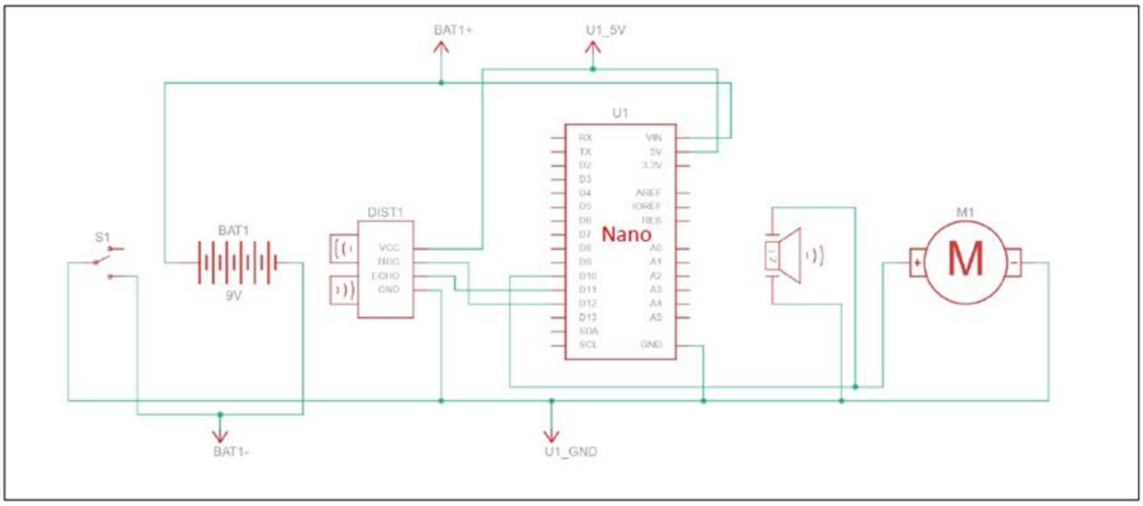

Figure 2. The Belt Circuit Diagram

Results and Discussion

The central control unit of the circuit is Arduino, which utilizes its built-in microprocessor to regulate all components. It operates based on the code provided to it. Arduino takes inputs from various sources, including the GPS and GSM tracking system, ultrasound sensor, and PIR sensor. The information from these inputs undergoes processing, and the outcomes are transmitted through the outputs, comprising a Buzzer and a DC Motor. The ultrasonic sensor is responsible for identifying obstacles in front of the blind person by measuring the distance between the person and the obstacle. An alert system is incorporated within the code, whereby if the distance is less than 100 cm, an intermittent alarm will sound, and the frequency of the sounds will increase as the person gets closer to the obstacle. When the distance between the blind person and the obstacle reduces to 20 cm, a continuous sound, similar to a sensitive car alarm system, will be emitted. The PIR sensor is a motion sensor designed to detect variations in infrared radiation.

Commonly utilized in security systems, motion-activated lighting, and other applications where detecting movement is crucial, this sensor incorporates a special material capable of generating a small electrical signal upon absorbing infrared radiation. When a person or object moves within the sensor's field of view, the temperature in the area alters, and the PIR sensor identifies this change in infrared radiation. Figure 3.3 illustrates the process of detecting the object using the PIR sensor. The GPS Module is a sensor that captures location coordinates from latitude and longitude, as depicted in Figure 4.4 It commonly utilizes the NMEA (National Marine Electronics Association) protocol, a standardized format for transmitting GPS data.

The GPS sensor outputs data in NMEA format, which can be read by the Arduino through the GSM module. The GSM Module is a chip that receives readings from the Global Positioning System (GPS) and transmits them as a text message to a designated phone number specified in the code. By calling the chip's number within the GSM, as illustrated in Figure 5 .5, the data can be retrieved and sent accordingly. The DC motor generates vibrations to alert the blind person when they are in a noisy environment where the sound of the buzzer may not be audible. The Buzzer is regulated through the code, which is responsible for producing intermittent sounds as the blind person approaches the obstacle. The circuit receives its electrical power from the battery, and the switch is employed to activate or deactivate the circuit.

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Figure 3. Screenshot PIR sensor alerts

The figure presented below demonstrates the function of the PIR (Passive Infrared) sensor alarm system incorporated into the assistive device. The PIR sensor measures changes in infrared radiation in the field of view with fluctuations in the temperature generally accompanied by movement. In the event of such a change, the sensor raises an alarm, thus calling for an appropriately initiate change. This screenshot shows that motion or the presence of an object is detected by the system, which is a major benefit of using it for the blind as they will be able to maneuver around their surroundings with little or no risks of an accident.

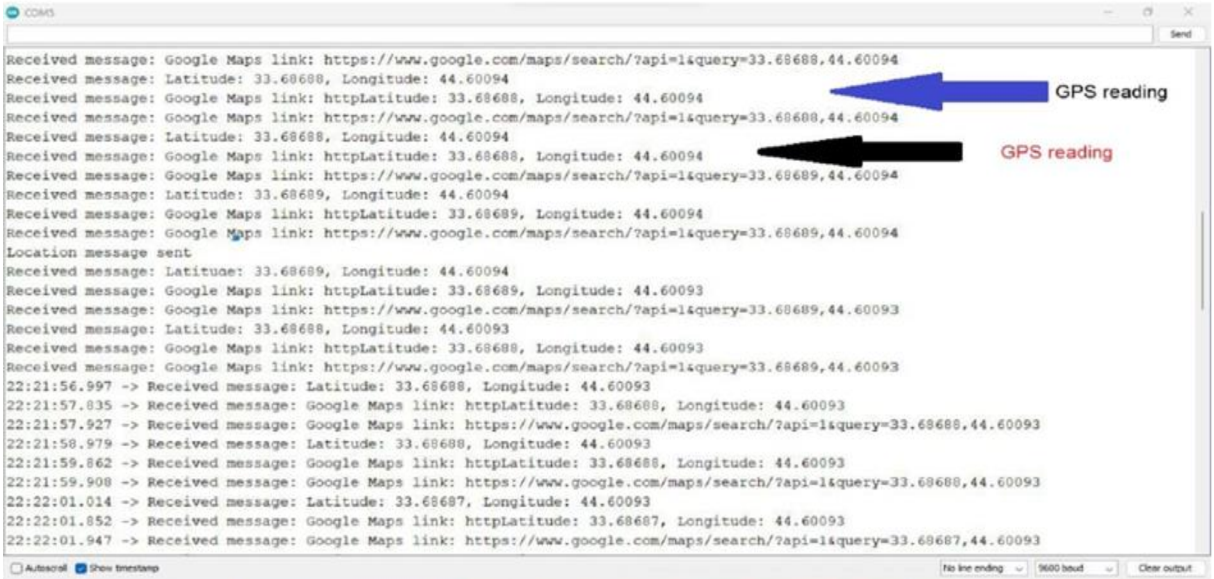

Figure 4. Screenshot GPS reading

Shown in Figure 4 is a screenshot depicting GPS reading that is employed in the context of the wearable assistive device. By virtue of the GPS unit, the location of the visually impaired user can be pinpointed via GPS coordinates and this consists of the latitude and longitude of the said user. This data is useful for the tracking of the user's location in real-time as well as for sending data about the user's location automatically to a predefined telephone number through the GSM module. It probably illustrates exactly what is displayed on the GPS data output that one can get for an alert or to locate a place.

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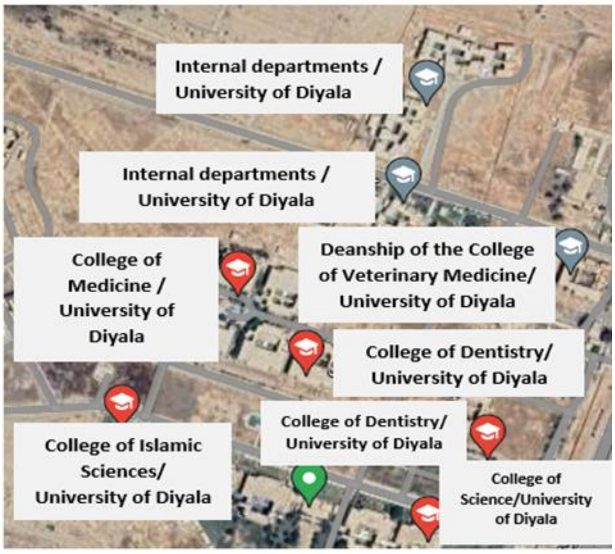
https://www.google.com/maps/search/university+of+diyala+%2F+college+of+medicine/@33.6849743,44.6025109,16z/data=!3m1!4b1?entry=tt



https://www.google.com/maps/search/university+of+diyala+%2F+college+of+medicine/@33.6849921,44.6046352,1449m/data=!3m1!1e3?entry=ttu

Figure 5. Screenshot for (a) GSM sends the location, (b) Receive the message from the GSM on the phone, (c) Open the maps link in the message

This figure consists of three parts: GSM Send the Location: Illustrates the procedure in which the GPS information acquired by GSM module is transferred to a specific phone number. This is of paramount importance especially in scenarios whereby the user requires the assistance of the caregiver or a family member tracing the location of the user. (b) Receive the Message from the GSM on the Phone: Illustrates how the location data is received in mobile phone. This page is a text message format of the user's location details as shown by the following screenshot. (c) Open the Maps Link in the Message: Explores how the receiver is able to open the received message in a map application with the user's location pinpointed on a map. This feature is a plus especially to a blind user as they can easily locate themselves whenever they are lost.

Arduino serves as the central board that regulates all components of the circuit through its internal microprocessor, operating based on the code provided. It receives inputs from the ultrasonic sensor, processes them, and subsequently delivers the results through the outputs, which are represented by the buzzer and the DC motor. The ultrasonic sensor in this circuit notifies the blind person about changes in the ground surface, based on the distance specified in the code from the person's waist to the ground (If the distance is greater than 105 cm, the alert indicates a depression in the ground surface, and if the distance is less than 95 cm, the alert indicates a rise in the ground surface. However, distances between 95 and 105 cm are considered normal with no warning). The Buzzer is responsible for producing intermittent sounds as the blind person approaches the obstacle, which is controlled through the code. The DC Motor generates vibrations to alert the blind person in situations where they may be in a noisy environment and unable to hear the sound of the alarm from the buzzer. The switch is utilized to activate and deactivate the circuit. And Similar to the glove circuit, the battery provides the electrical energy required for this circuit.

We have designed the portable and wearable assistive devices for blind people, Figure 6.6 Shown the final Glove, a Glove that are focused on helping those people who are blind or hard of communication without using internet and the final shape of the belt shown in Figure 7.7, that help them to move easily without cane.

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Figure 6. the final configuration and design of the glove

As seen from the architectural design plan laid out in figure 6 above, the wearable glove consists of several sensors and components such as the ultrasonic sensor, PIR sensor, GPS module, GSM module, buzzer and a motor for vibrations. This glove is one of the components of the assistive system that helps blind and partially sighted people avoid obstacles and navigate by vibration or sound signals. The figure illustrates the use of the glove when it has been worn and is ready for use.

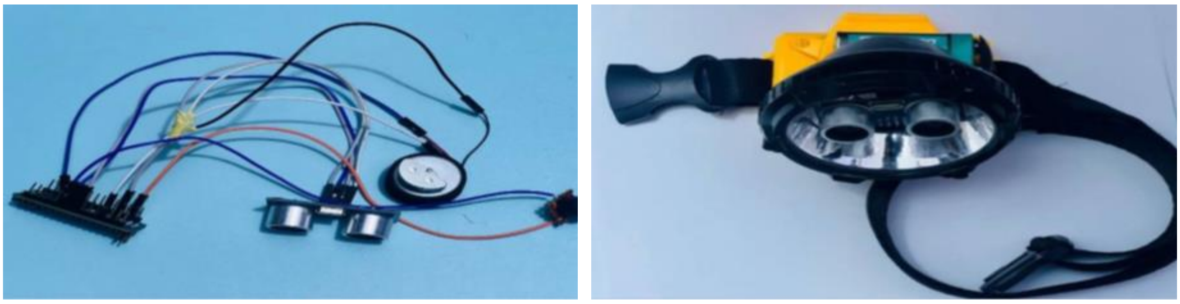

Figure 7. the final configuration and design of the belt

Figure 7 shows the last design of one more component of the assistive system, which is a wearable belt. It is fitted with an ultrasonic sensor, buzzer, motor, and an Arduino chip through which it detects obstacles and low-level objects. This belt is designed to be worn around the waist and as mentioned earlier in the article, the glove is designed to complement the belt in offering help to visually impaired people. The design illustrated in the figure tends towards the portability and convenience of the device, while still attempting to allow for comfortable wear and straightforward navigation assistance.

It is true that the synchronization of ultrasonic, PIR, GPS, and GSM sensors in a single wearable system is a technical accomplishment. Ultrasonic sensors which are found to be very much accurate in distance measurement since they work based on the time of flight have been used in many assistive devices because of their reliability and comparatively low cost (Zhang et al., 2023). However, they are not devoid of their difficulties in implementation. As for ultrasonic sensors, for example, their operation depends on temperature and reflective surfaces, which cause distortion of the measured values and possible false positives or false negatives (Wang & Li, 2024). PIR sensors increase value by detecting movement; however, their capacity is only as a change in infrared radiation, thus potentially ineffective in environments where there are minor temperature differences or where the obstacle being a threat is not moving (Khan et al., 2023).

The presence of the GPS and the GSM modules therein adds a layer of safety that goes beyond that of an assistive device in that it offers tracking and communication in real-time. But the mentioned GSM networks dependency opens issues, especially when there is a low level of

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cellular connectivity or when GPS signals are absent, which can occur indoors (Chen et al., 2023). There arises a concern of whether the system can effectively meet the real life requirements especially in situations where the network connectivity may be poor in areas of poor connection such as in the rural areas or heavily populated urban zones with many buildings.

If we compare the proposed system with the existing technologies like white cane or guide dogs, then following apparent benefits of proposed system are easy to identify. Thus, commonly used white canes can merely offer simple, only touch-based responses while sometimes missing objects above the height of the cane holder or at longer distances (Ali et al., 2023). In the same way, although guide dogs provide a more extensive type of assistance, their practical application is limited due to the expensiveness of the procedure, the constant costs of dog maintenance, and the users' propensity to develop allergies (Gifford et al., 2022). However, the wearable system has to be examined for its true value prop as compared to a traditional Figure. It was further established that the inclusion of several sensors in a single wearable device, as much as this is considered a new development, does present a better solution. The NavGuide system for instance contains ultrasonic sensors, in addition to offering sound and vibration feedback akin to the device involved in this study, but has been reviewed as only being capable of perceiving raised or slowly moving barriers (Patil et al., 2022). Incorporation of GPS and GSM modules in the current system limit the above mentioned limitation thru location tracking however achieving a better user autonomy thru this addition is still questionable as this might increase the complexity of the system and might result to overload of user.

Moreover, the latest works have also stressed how the user experience and the psychological aspects of the assistive technologies have as well. For instance, Smith et al. (2022) stated that, the performance of the assistive devices does not wholly depend on the device's ability, but rather how naturally the users can operate on the device. The glove and belt system may be too complicated, even though they have application of advanced technology, this can dissuade many customers from using them especially those with low intelligence or users with mechanical difficulties. There is a need to expand the analysis of this type of use as it could define if it is sustainable or not for the device.

The system is planned in such a way that the freedom of the visually impaired can be achieved with the help of real time information about the environment. However, a more nuanced consideration reveals a potential paradox: , although the device brings enhanced navigational aids, the main idea in making such a gadget could lead to over domination by the technology hence taping the user's confidence in his or her inherent navigation ability or traditional aid like the white stick (Hussain et al., 2023). This concern is more accentuated as reliance on the technology demises one's ability to navigate with a device which eventually is unhelpful in case the device malfunctions or is not accessible. However, the psychological factor that comes along with it such as the embarrassment of wearing such a device cannot be overemphasized. Lee et al. (2023) also argue that, wearables may dehumanize or marginalize the users; this is in cases where the devices are obvious or when they develop a hitch in a public domain. The glove and belt although being portable require some aspects of wear and tear in order not to give users the feeling of being more dependent on the contraption, the aspects should therefore be discreet.

Conclusion

Currently, with significant advancements in electronics and the revolutionary changes in the device industry, various innovations have emerged to enhance human lives, particularly for patients, such as the visually impaired. In response to this development, our device was created to assist the blind in navigating and avoiding obstacles, thereby promoting greater

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independence for them when they are unaccompanied. The current paper introduces a two-part device comprising a glove and a belt, each equipped with its own distinct circuitry. The glove circuit comprises an ultrasonic sensor, a PIR sensor, a GPS module, a GSM module, audio outputs, and a vibration-generating motor. The ultrasonic sensor operates by emitting waves forward to detect obstacles or objects in its path. The belt incorporates a circuit that includes an ultrasonic sensor, an audio output, a motor for generating vibrations, and an Arduino chip responsible for controlling all the components. Its purpose is to notify the blind about any changes in ground level, whether it's an elevation or a descent.

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