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Research Article

Design and Implementation of a Walking Smart Stick for the Visually Impaired and the Blind

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Abstract: In this paper, researchers have developed a simple smart stick. With the help of this smart stick, blind and visually impaired people will be able to do daily tasks with greater mobility and independence. The suggested project entails creating a lightweight cane with several sensors that an Arduino will be used to control. The sensors are used to transmit signals to the Arduino board that has been coded. This board is then connected to an alarm device that has vibrators and sirens, as well as some voice clips that have been recorded to safely guide the blind. The cane has a sound socket as well, which is not present in most conventional canes. This is used to manage auxiliary parts that notify the user about the obstacle's substance, shape, and direction. The smart stick runs on a battery and is lightweight. Thus, it is an inventive, user-friendly, and reasonably priced option for those who are blind or visually handicapped. Compared to conventional canes, it is more affordable and has a deficient power consumption.

Keywords: Walking Smart Stick, Sensors, Arduino board

1. Introduction

According to projections provided by the 2019 Blindness and Vision Impairment Collaborators of the Global Vision Database, the year 2020 witnessed approximately 43.3 million individuals experiencing blindness, while 295 million individuals confronted moderate to severe vision impairments. Anticipations for the year 2050 suggest an escalation in these numbers, with an estimated 61.0 million individuals projected to be affected by blindness and 474 million individuals expected to contend with moderate to severe vision impairments [1,2]. The eyes, which serve as the organs of vision, hold significant importance within the realm of human physiology due to their capacity to absorb and analyze visual information before transmitting it to the brain. Moreover, it is imperative to acknowledge that eyes hold significant importance in human existence, as evidenced by the fact that a substantial 83% of environmental information is acquired by visual perception [3,4].

Nevertheless, there is a significant portion of the global population that lacks access to this privilege. There exist several profound disabilities, among which blindness is included, wherein individuals encounter numerous challenges despite the presence of various technological developments. Based on research [5] published by the World Health Organization (WHO) on October 11, 2017, it is estimated that there are around 253 million individuals worldwide who experience visual impairment. Among this population, 36 million individuals are classified as completely blind, while 217 million individuals have varying degrees of vision impairment ranging from mild to severe [6]. Chronic eye illnesses are responsible for the majority of cases of vision loss, accounting for around 85% of all instances. Among the overall proportion of individuals with impaired vision, 81% are aged 50 years or older, while the remaining 19% are those under the age of 15 years. The majority of individuals who are visually impaired are concentrated in low-income or developing nations, particularly in the regions of Africa and Asia. Based on recent statistical data, it is anticipated that the prevalence of vision impairment may see a threefold increase by the year 2050 [7,8].

The design of a lightweight, adjustable cane with a handle head and stick elongator, as well as several sensors linked to an Arduino board, are all included in the proposed work. The device's main base frame is a traditional white cane. It can scan a predetermined area, including known and unknown locations around the blind, by emitting reflecting waves with the aid of that blind stick. Ultrasonic and infrared sensors are mounted at the appropriate locations to detect obstacles. The fitted sensors connect with the alarm unit, which has a buzzer and vibrator, by sending signals to an Arduino-programmed board. some recorded audio clips to navigate blind people safely. The blind cane has an audio jack as well, which is not present in most traditional canes [9,10]. The system is also capable of controlling the parts of the obstacle that alert the user to its shape, material, and direction. The gadget is battery-operated and small in weight. As a result, the device is simple to use and offers blind and visually impaired people an inventive, affordable alternative. The stick is more cost-effective than the traditional one and has excessively low power consumption.

This walking assistance works well with the cane, is lightweight, and doesn't get in the way when using the cane. Door recognition in corridors now complements path and obstacle detection that are just beyond the cane's reach. This is essential for discovering a specific room, improving perception of the surroundings, and localizing. A smart audio interface can help the user focus on walkways and passageways by warning them of impending hazards so they can avoid them [11]. The creation of a mobile hand-carrying aid with a smart sensor logic system that is a smart path guidance system for the blind and visually impaired for the chosen design, a suitable model with embedded fuzzy logic decisions has been created. To confirm the behavior of the system, a proposed solution is additionally tested for a range of condition inputs. The sensors are calibrated after multiple trials to improve judgment accuracy. This allows a blind person to move freely in a strange place [12].

Technical support is given so that they can rely on themselves to find roadblocks and puddles on their daily journey. Android apps and a walking stick make up this system. With the use of Internet of Things technology, the included walking stick can help people with impairments live better lives by offering support and assistance. The Global Positioning System (GPS) unit, several sensors, a modern and sophisticated microcontroller, and additional alarm-related components are all essential to the system's architecture. Sensors detect obstacles, and depending on what kind of obstacle it is, the VCP receives vibrations or auditory sounds as notifications. For parental tracking, the GPS module receives location coordinates from the VCP. With a single tap of the app, users can instantly interact with their friends or parents with the SOS (Save Our Selves) button [13]. A suitable device that notifies the user regarding obstacles. The use of ultrasonic sensors for sensing object distance is significant.

For those who are blind or visually handicapped, this aid gadget may be more autonomous and self-sufficient. With the aid of a reliable and efficient GPS-connected navigation device, it facilitates travel to unknown locations as well as unfamiliar routes. The atmosphere is welcoming to those who are visually impaired due to its vast potential and high precision and reliability. various forms of navigation, including position-based, velocity-based, and acceleration-based navigation. Here, navigation truly refers to moving from one location to another for a deliberate activity [14].

To enhance the existing stick's capacity to combine identifications that are deterrents above and below the knee. The bamboo stick only uses ultrasonic sensors to identify obstacles before coming into contact with them and a water detection sensor to identify any water present on the path. Depending on where the obstruction is, it provides the operator with vibration and various audible feedback. Excellent trial results were obtained from a volunteer who was blinded and guided along an impeded path. The outcomes guarantee prompt identification, safety, and faster user mobility. The simulations that were run were precise and pertinent to the paper's main objective. The blind can be guided indoors or outdoors with the use of an electric bamboo walking stick [15].

People who are blind can avoid hazards and obstacles when walking with the use of a wearable vest. The vest that blind individuals wear has ultrasonic sensors connected to it that allow it to detect objects. Apart from object detection, the suggested system tracks the whereabouts of visually impaired individuals using a GPS and GSM module. When an obstacle is detected, the device vibrates to warn the user. If the user approaches, a second alert will sound, informing the visually impaired user of the impediment's location (e.g., left or right side). According to the trial findings, the suggested system can identify objects up to 120 cm away and instantly sound an alert so that a blind person can react [16].

If the blind has trouble finding their way home, families can actively receive an emergency help signal from the blind. The stick has an emergency push button that, when depressed, will transmit the coordinates as a brief text message to the family's phone number. Blind individuals can recognize impediments ahead of them when traveling because of an ultrasonic sensor system on the stick. Anything within 100 centimeters of the sensor can be detected. The sensor will play an appetizing sound for blind people if it detects an object that is fewer than 100 centimeters away. Based on observations, the designed stick performs well, with an average GPS module error of 11.89 meters [17].

The system consists of Android applications (APPs) and a walking stick. The walking stick has sensors, a global position system (GPS) module, a Raspberry Pi, and a programmable interface controller (PIC) integrated as a control kernel, as well as alert-generating components. Obstacles can be identified with the use of sensors, and the VCP is alerted about them via buzzers or vibrations. Parents can use an application to track their child's location after the GPS module receives the coordinates of the VCP. An additional crucial application is utilized, known as an emergency application, which enables the VCP to instantly contact friends or parents by just shaking their phone or pressing the power button four times in five seconds during an emergency [18]. Moreover, a unique method of assistance is in the shape of a blind stick that guides them and emits a beeping alarm to warn them. An ultrasonic sensor can be used to find obstructions or any other object with ease. Thus, a blind individual could be easily tracked using a GPS system. A microphone and speaker can be used to determine the current position of visually impaired individuals if a relative is interested in knowing. With the aid of GSM, they might communicate with a relative in case of any issues. The blind can benefit from an Internet of Things initiative, and a blind stick has sensors connected to it. With this stick, they may walk safely, and they can move from one place to another.

2. The Walking Smart Stick

The following components make up the built-in system known as the Smart Stick for the Blind: two ultrasonic sensors that can identify obstacles in front of a visually impaired person from ground level to head level; an infrared sensor that can identify stairs that are rising or falling; a water sensor; and a heat sensor that can identify puddles. Figure 1 illustrates the walking smart stick.

Figure 1. The Walking Smart Stick

When the stick is poised to come into contact with an obstruction, vibration sensors, and a buzzer are utilized to whistle and vibrate. A button on the device allows the user to adjust the vibration range. The suggested solution enhances existing system designs with a cutting-edge microcontroller created especially for Internet of Things applications. This makes the system more user-friendly, practical, and efficient. Real-time data collection from the sensors will be sent to the Arduino board for processing.

Following processing, the Arduino starts up the warning system that sends vibrations and sounds to the sensors to warn the person. The rechargeable battery powers the system. Walking might become challenging and exhausting if the Smart Stick is chosen incorrectly in length. This could cause you to walk slower than you would like or faster than your cane will allow, which could annoy you or put you in danger of running into people or things. Therefore, selecting a stick that is too short may be awkward and may complicate movement needlessly.

Thus, we must modify the stick's height according to the person's height. Other than that, there is no set length for the Smart Stick that should be used; instead, you should experiment to find the length that is easiest to use, comfortable, and natural for you. The height of the stick is therefore either fixed or adjustable in accordance with the instructions that follow. Selecting a smart stick that extends from the floor to your chest or sternum when you stand straight up is one of the most widely used measuring techniques. Some people prefer a stick, or a stick with one end touching the floor and the other reaching your chin when you and the stick are standing upright. Ultrasonic sensors periodically produce brief, high-frequency sound pulses. They dispersed at the speed of sound across the atmosphere. When they come into contact with an object, the combination of infrared and ultrasonic sensors provides a supplementary system that can accurately determine the distance.

A. Ultrasonic sensor device:

An ultrasonic sensor device is an electronic instrument designed to detect and measure distances, as well as to identify the presence of objects within its proximity through the use of ultrasonic waves. This sensor typically employs ultrasonic transducers to emit high-frequency sound waves and then measures the time it takes for the waves to reflect off nearby objects and return to the sensor [19]. The obtained data is then processed to calculate the distance between the sensor and the object in question. Ultrasonic sensor devices find diverse applications in various fields, including industrial automation, robotics, automotive systems, and smart devices [20]. Their non-contact nature, accuracy, and reliability make them particularly advantageous for tasks such as object detection, obstacle avoidance, and distance measurement. These devices contribute significantly to enhancing automation processes, promoting safety, and facilitating precise control in numerous technological applications [21]. The ultrasonic sensor measures the distance between barriers and themselves. It measures the separation between the stick and the obstructions in front of it since it is fastened to the stick, as demonstrated in Figure 2.

Figure 2. Ultrasonic sensor device

B. LED lighting sensor

Another name for an LDR (light-dependent resistor) is an optical conductor or photoresistor. The basic idea behind how an LDR functions is that as the amount of light around a sensor grows, the resistance within a few ohms' lowers, and as the amount of light surrounding the sensor falls, the resistance increases up to mega ohms [22-24]. During the night, the attached LED system will light up and function as a flashlight, which others can clearly detect because the LDR has a high resistance and the current passes through it instead.

C. Battery system

The battery system is a crucial component of the design, emphasizing affordability and compact dimensions. A cost-effective 9 V battery, illustrated in Figure 3, was chosen for implementation in the system. This choice aligns with the design's overarching principles of cost efficiency and minimal spatial footprint [25,26]. The battery system plays a pivotal role in the overall functionality of the design, and its features are tailored to meet specific criteria:

- Affordability: The chosen battery is cost-effective, aligning with the project's objective to maintain an economical design without compromising performance.
- Voltage: The battery operates at 9V, providing an optimal power supply for the system. This voltage was selected after careful consideration of the power requirements and efficiency of the components.
- Compact Design: Emphasizing a compact form factor, the chosen battery contributes to the overall small size of the system. This is crucial for ensuring portability and ease of use, particularly in applications where space is a limiting factor.
- Accessibility: The ubiquity of 9V batteries ensures easy availability, making replacements or obtaining spare batteries a convenient task for users.
- Energy Efficiency: While the battery system is designed for affordability, it also prioritizes energy efficiency to maximize the operational life of the system on a single battery charge.

The integration of this battery system underscores the commitment to creating a practical, cost-efficient, and user-friendly solution for the intended application.

Figure 3. Battery system

D. Arduino control system

Arduino stands out as a remarkable platform that seamlessly integrates both open-source software and hardware components. Its programming environment, characterized by its openness and freedom, is not only cost-free but also invites global programmers to contribute, enhance, and introduce novel features. This collaborative effort has fostered a vibrant community that continually refines and expands the capabilities of Arduino [27,28]. One distinctive aspect of Arduino is the accessibility of all designs associated with its boards, which are made freely available to the public. Figure 4 shows the Arduino control system. This commitment to openness encourages transparency and the sharing of knowledge. Programmers, hobbyists, and professionals alike benefit from the wealth of information and resources, fostering a culture of innovation and learning. The heart of Arduino lies in its hardware modules, and understanding their operation is crucial for anyone working with this system [29,30].

Figure 4. The Arduino control system.

3. Features of the Walking Smart Stick

The Walking Smart Stick incorporates several innovative features to enhance its usability and effectiveness in aiding individuals with visual impairments. Here are the key features:

- Automatic LED lights that use red LDR at night are high-intensity LED lights.
- A tiny strip of LEDs at the top.
- More cost-effective and efficient than alternative gadgets.
- Make it easier to identify the obstacles.
- The system stands out in comparison to other systems that use a CPU, I/O devices, and discrete memory because of its small size and low cost.
- A common microcontroller is a mixed-signal microcontroller, which integrates the analog components required to manage electrical devices that are not digital.

The Walking Smart Stick emerges as a user-friendly and economically viable solution for individuals with visual impairments. Integrating various sensory modalities and employing a compact design with a common microcontroller, represents an advancement in assistive technology for safer and more accessible navigation.

4. Procedure for the Proposed System

The proposed system presents a groundbreaking solution aimed at enhancing safety and navigation for elderly and visually impaired individuals, particularly in both familiar and unfamiliar environments. Recognizing the indispensable role, a walking stick plays in navigation for these individuals, the system leverages technology to augment its functionality, providing invaluable support and increased safety during movement. For blind and elderly individuals, a walking stick is more than just a physical aid; it serves as a key communication tool for navigation. The proposed system takes this fundamental tool and transforms it into a smart electronic aid, introducing a concept aligned with the Internet of Things (IoT). This innovation goes beyond the conventional role of a walking stick by offering real-time assistance in understanding the surrounding environmental scenario.

One of the significant benefits of the proposed system is its capacity to contribute to the safety and confidence of users during movement. By incorporating sensors and alert mechanisms, the system acts as a protective shield, preventing collisions with objects or obstacles. The implementation of sound alerts plays a pivotal role in notifying the user about potential obstacles in their path. This auditory feedback not only provides information but also aids in developing and refining the user's sense of spatial awareness through sound localization. The overall concept revolves around providing real-time assistance by relaying information about the surrounding environment. In essence, it becomes a supportive companion for individuals with visual impairments or those who may face challenges in navigating their surroundings independently. In the quest for precision and reliability in short-distance measurements, the utilization of an ultrasonic sensor is a prudent and commendable choice. The term "ultrasonic" pertains to sound frequencies beyond the audible range for humans, typically above 20,000 hertz. The HC-SR04 ultrasonic sensor, in particular, offers a balance of accuracy and efficiency across short distances, making it a favorable component for the proposed system. One of the fundamental considerations in integrating the ultrasonic sensor with the Raspberry Pi involves the disparity in voltage levels. The HC-SR04 sensor operates with a 5-volt output signal, while the GPIO pins of the Raspberry Pi function at 3.3 volts. This incongruity necessitates a strategic approach to ensure seamless compatibility.

A crucial solution to this voltage mismatch involves the implementation of a voltage-divider circuit. This circuit, comprised of two resistors, acts as an intermediary, adjusting the 5-volt output signal from the ultrasonic sensor to a compatible 3.3 volts for input into the Raspberry Pi's GPIO pin. This voltage division ensures that the signal is within the acceptable operating range of the Raspberry Pi, facilitating harmonious communication between the sensor and the microcontroller. By addressing voltage compatibility through a well-designed circuit, the integration of the ultrasonic sensor becomes not only feasible but also optimized for the specific requirements of the Raspberry Pi. This strategic alignment of components underscores the meticulous planning and engineering considerations involved in creating a seamless and effective system. Choosing the HC-SR04 ultrasonic sensor and putting in a voltage divider circuit shows that the sensor integration was well-thought-out and technically sound. This meticulous attention to detail ensures that the system operates with precision, reliability, and the necessary compatibility between components.

5. Software Implementation

The programming language C was employed to articulate the system program for the Arduino, delineated through a comprehensive flow chart explicating the system's integration and operational procedures. The initiation transpires through the resetting of information ports coupled with the provision of battery power to the framework. Outputs from ultrasonic sensors denoted as US1, US2, and US3, are manifested through light-emitting diodes (LED), a buzzer, and a vibrator. In scenarios where US1 detects an obstacle within a proximity of less than 1.5 meters, the LED and buzzer exclusively activate. Similarly, if US1 identifies an obstruction within a range below 1.0 meters, the LED, vibrator, and buzzer synchronously engage. Figure 5, presents software implementation.

Moreover, auditory signals in the form of the buzzer, LED, and vibration persist when US2 detects pits or potholes exceeding a separation of 0.2 meters. Subsequently, the vibration, LED, and buzzer are triggered upon the identification of water by the water sensor. Each specific location is characterized by a unique vibration design and signal type. Internet of Things (IoT) devices represent an emergent and rapidly expanding technological domain that transcends conventional boundaries, harnessing the computational capabilities of diverse devices to address multifaceted challenges. IoT application programs facilitate real-time monitoring, localization, and analytical procedures. Contextual data, encompassing elements such as physical surroundings, user activity, speed, and orientation, as well as temporal factors like the day, week, temperature, and meteorological conditions, assume pivotal roles in this system.

Typically, a GPS receiver compares a position against a digital map before conveying notifications to the user. Visual impairments manifest in diverse forms, including blindness, central vision loss, and peripheral vision loss. The IoT-based platform emerges as particularly pertinent and fitting for meeting precise human demand requirements. The IoT platform's increased effectiveness, adaptability, dependability, and versatility in dealing with various situations are the driving forces behind its choice. The integration of various devices with the IoT platform is facilitated through application gateways.

```
// defines pins numbers
const int trigPin = 9;
const int echoPin = 10;
const int buzzer = 11;
const int ledPin = 13;
// defines pins numbers
const int trigPin = 9;
const int echoPin = 10;
const int buzzer = 11;
const int ledPin = 13;
// defines variables
long duration;
int distance;
int safetyDistance;
void setup() {
pinMode(trigPin, OUTPUT); // Sets the trigPin as an Output
pinMode(echoPin, INPUT); // Sets the echoPin as an Input
pinMode(buzzer, OUTPUT);
pinMode(ledPin, OUTPUT);
Serial.begin(9600); // Starts the serial communication
}
// Sets the trigPin on HIGH state for 10 micro seconds
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
// Reads the echoPin, returns the sound wave travel time in microseconds
duration = pulseIn(echoPin, HIGH);
// Calculating the distance
distance= duration*0.034/2;
```

```
safetyDistance = distance;
if (safetyDistance <= 20){
  digitalWrite(buzzer, HIGH);
  digitalWrite(ledPin, HIGH);
}
else{
  digitalWrite(buzzer, LOW);
  digitalWrite(ledPin, LOW);
}
// Prints the distance on the Serial Monitor
Serial.print("Distance: ");
Serial.println(distance);
}
```

Figure 5. Software implementation.

6. Conclusion

The development of a cost-effective, adaptable, and user-friendly electronic intelligent walking stick system represents a significant advancement in aiding blind individuals, particularly among the elderly and children. The Smart Stick, equipped with a variety of sensors, is designed to enhance pedestrian navigation and provide alerts for potential discomfort or hazards. This innovation aims to empower blind individuals, fostering greater independence and self-reliance in their daily lives. Key features of the Smart Stick include a diverse array of sensors that contribute to its effectiveness. The incorporation of infrared sensors allows the device to identify the origin and proximity of encountered objects. This capability enhances the mobility and perceptual capabilities of blind individuals, enabling them to navigate their surroundings with greater confidence and autonomy. One notable aspect of the system is its ability to issue alerts in response to potential discomfort or hazards. This real-time feedback mechanism adds an extra layer of safety, allowing users to respond promptly to their environment. The system's adaptability ensures that it can cater to the diverse needs of blind individuals without requiring specialized training.

The use of infrared sensors is particularly commendable, as it facilitates secure and autonomous mobility. The device's ability to identify objects and obstacles in the user's path contributes to a safer navigation experience. Importantly, this approach eliminates the need for extensive training and minimizes the burden of carrying large and cumbersome devices, making it more user-friendly for individuals of different ages. In conclusion, the development of this cost-effective, adaptable, and user-friendly electronic intelligent walking stick system represents a valuable contribution to the well-being of blind individuals, particularly the elderly and children. By enhancing mobility and perceptual capabilities in a secure and autonomous manner, the Smart Stick aims to improve the quality of life for its users, fostering greater independence and self-reliance.

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