Smart Walking Stick for the Visually Impaired using NodeMCU ESP32

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Abstract— It is a real challenge when we try to move through an unknown environment and can't rely on our own eyes. Visually impaired people face this problem every day of their lives. They usually rely on a walking stick for navigation. They use the walking stick to detect static obstacles on the ground, stairs, holes and uneven surfaces through simple tactile-force feedback. Though it is light and portable, its range is limited to its own size and is not suitable for dynamic components. This paper focuses on developing a Smart Walking Stick using the NodeMCU ESP32 to help the visually impaired people to walk more confidently by providing information about their environment. Ultrasonic sensors are used to detect obstacles, pits, and stairs that lie ahead and to alert them of the same, thereby reducing the amount of accidents while walking. Water sensing pins are used to detect wet surfaces. The stick is programmed to connect automatically to the Android phone using Wi-Fi for sending sensor data, for giving auditory feedback to the user and also for determining the best route to be taken to reach a new location by integrating GPS technology. If the stick is dropped accidently, the touch sensing pins send a signal to the buzzer which will help the user to locate it easily. SMS alert facility is also provided in case of emergency situations.
Keywords: GPS Technology, Smart Walking Stick, EOA, RFID

I. INTRODUCTION

Visual Impairment is defined as reduced vision not corrected by glasses or contact lenses. The main causes of impairment of vision include uncorrected refractive errors, cataracts, glaucoma, etc. Refractive errors include far sighted, near sighted, presbyopia, and astigmatism. The most common cause of blindness is cataract. Other disorders that may result in vision problems include age related macular degeneration, corneal clouding, diabetic retinopathy, childhood blindness, and a variety of infections [1].

According to the World Health Organization (WHO) and International Agency for Prevention of Blindness (IAPB), there are approximately about 285 million visually impaired people worldwide, of which 39 million people are blind and 246 million people have low vision (moderate or severe). About 90% of the world's visually impaired live in developing countries. A report by WHO and IAPB stated that by 2020, the number of blind people will increase worldwide to reach the double [2].

A visually-impaired person commonly uses a walking stick for navigation. The basic walking stick is a purely mechanical device used to detect static obstacles on the ground, stairs, holes and uneven surfaces through simple tactile-force feedback. Although this device is portable and light, its range is limited to its own size and is not suitable for dynamic components. Another option that provides travel aid for the blind is guide dogs. Based on the symbiosis between the dog and the visually impaired owner, the training and relationship with the animal are the keys to success. But guide dogs are far from affordable and their average working time is just about 7 years [3].

In order to assist visually challenged people to be more self-reliant and to walk confidently, a Smart Walking Stick is proposed. The Smart Walking Stick will alert the visually impaired people of obstacles, pits, stairs and water that lie ahead of them and thereby reduce the amount of accidents while walking. It will consist of a walking stick equipped with sensors to gather information about the surrounding. The user will also be able to reach a destination by choosing a destination and the route to be taken will be determined by GPS technology that will be integrated into the system. Thus, by providing the visually impaired with a sense of artificial vision, they can safely and conveniently overcome their difficulties of moving about every day.

Section II presents the study of the existing systems, their working and limitations. Section III includes the architecture of the proposed system and the various scenarios in which it will function.

II. EXISTING SYSTEM

Visually impaired people rely on different forms of assistive technology in order to reduce their dependence on others. These technologies can be categorized into either visual enhancement, visual substitution or visual replacement. This project deals with a type of visual substitution technology, which can be further classified into Electronic Orientation Aids (EOA), Electronic Travel Aids (ETA) or Position Locator Devices (PLD). EOA help the visually impaired to find their way, ETA prevent them from walking into obstacles, while PLD monitor their location using GPS. These visual assistance technologies can be either online or offline. They may be suitable for indoor usage or outdoor usage or both. They may be used either during the day or the night or at both times. Their coverage may be limited either to short, medium or large range. And they may be used to detect either static or dynamic obstacles or both.

This section provides information about currently existing walking sticks that help the visually challenged remain self-dependent. These walking sticks have similar characteristics like they work offline, have a medium range, can be used to detect dynamic obstacles to a certain extent and are to be used outdoors and during the day. The most commonly used ones are as follows:

A. *Basic White Cane*

The most commonly used walking aid by visually-impaired people is the basic white cane. It is simple & purely mechanical. It makes use of tactile-force feedback [3]. It is used for the detection of static obstacles on ground, uneven surfaces, potholes and stairs. It works offline and is suitable indoors and to some extent outdoors. It can be used during day as well as night, but is short-ranged and cannot be used to detect dynamic obstacles.

The basic white cane comes in two forms, the straight cane and the folding cane. The latter is composed of a long tube of fiberglass or aluminium with a handle on one end and a metal or nylon tip at the other. The handle may have either a wrist loop or a small crook, which can be used for storing the cane when it is not in use. The folding cane looks similar to a straight cane except that the folding cane is broken up into several sections that are held together by an elastic chord running through the center of the tubing, allowing it to be held tightly together when unfolded, or folded away when it is not in use.

1) *Advantages:*
– It is light and portable.

2) *Disadvantages:*
– Its range is limited to its own size.
– It is not suitable for dynamic obstacles which are constantly in motion.

B. *IR-based Stick*

The IR-based stick makes use of infrared sensors, a feedback device (like a buzzer or vibrating motor) and a microcontroller. Infrared sensors can detect the motion of objects using the heat generated by them. An infrared sensor can be either active or passive. An active infrared sensor keeps emitting IR rays and when it doesn't get back the amount of rays it has reflected, it detects an object. IR systems are also used to calculate the distance from the object using the speed and time required for the light to be sent and received again [2]. Thus

distance = speed x time (1.1)

When the IR signal is received, the microcontroller module begins to compare the received and transmitted signals to identify obstacles standing in the way of the visually impaired. If it finds a difference in the phase and amplitude of the received and transmitted signals, it invokes the corresponding component to produce either an audio or tactile stimulus in response to the nearby object. The intensity of the sound or tactile vibration is inversely proportional to the distance from the object that lies ahead.

1) *Advantages:*
– It is used to calculate the distance from an object.
– Disadvantages:
– It cannot work in the dark.
– It is short-ranged (performance decreases for long ranges).
– External environment can affect the transmission.

C. *RFID-based Stick*

The RFID system contain three main parts: RFID tag or transponder, RFID reader or scanner and Host. The RFID-based stick contains the reader. A tag is attached to all the objects that the person may want to detect. The scanner first transmits power wirelessly to the tag. The microchip on the tag then transmits data to the scanner. The scanner finally sends this data to a connected phone for further processing. A designed application on the phone gives voice navigation based on the tags read and also updates person's location information on the server.

RFID Readers are of two different types, namely portable reader and fixed reader. RFID tags come in various forms. Some tags are made with metal to be used as screws and some are tiny enough to be embedded within the human body [4]. Tags may be attached to different places along the road such as public buildings to guide the user. Tags may store information about a location so the user may get to know the place better. The host may be a computer or a microcontroller.

1) *Advantages:*
– It retrieves information about the object that gets detected.

2) *Disadvantages:*
– It is not feasible to place tags at every location.
– The scanner and tag must be in range.
– It cannot detect untagged objects.
– The user has to wait till data is read from the tag.

D. *Ultrasonic-based Stick*

The ultrasonic-based stick makes use of an ultrasonic sensor, a feedback device (such as a buzzer) and a microcontroller. The ultrasonic sensor is used to find distance from an object using ultrasonic waves. The transmitter sends out high frequency signals while the receiver reads the signals relayed back from the object. On detecting obstacles, the sensor forwards this data to the microcontroller which then processes it and calculates if the obstacle is close enough. The circuit does nothing if the obstacle is not that close. If the obstacle is close, the microcontroller sends a signal to sound a buzzer. The frequency of the beep keeps changing with respect to the distance from the object i.e. the frequency is inversely proportional to the distance [5]. It is not a perfect system, but it is reliable and one of the best ways to sense proximity.

1) *Advantages:*
– It has low cost.
– It is not affected by colour or transparency of the object.
– It is resistant to dust, smoke or high moisture environment.
– It can be used in dark environment.

2) *Disadvantages:*
– It cannot differentiate between solids and liquids.
– It is not able to detect whether stick is in hand or not.
– Sensing accuracy is affected by soft materials.
– Sensing accuracy is affected by changes in temperature by 5-10 degrees or more.

III. Proposed System

The aim of the proposed system is to design and develop a light weight, easily affordable Smart Walking Stick for the visually impaired that will provide constant assistance and aid them in understanding their surrounding better by updating them with information of their environment by frequently sounding different alerts on detection of obstacles, water, lowered and elevated surfaces, as well as by guiding them to reach a particular location.

A. *Architecture of the Proposed System*

1) *Block Diagram*

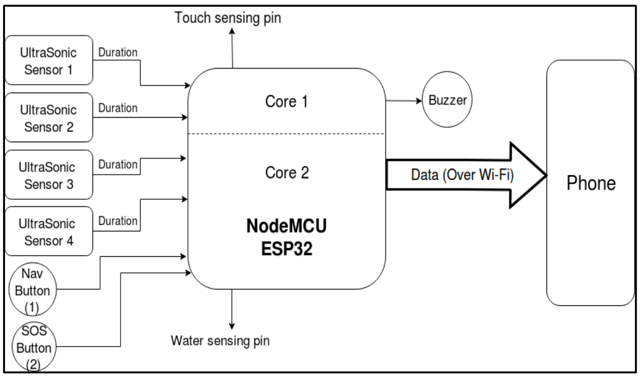

Fig. 1: Block Diagram of Smart Walking Stick

The block diagram of the proposed system consists of the NodeMCU ESP32 to which all the other components are interfaced. The components include four ultrasonic sensors, two push buttons (one for the navigation feature and the other for the emergency alert facility) and a buzzer. The capacitive sensing pins on the NodeMCU is used for touch sensing and wet surface detection. The Android phone is connected to the NodeMCU using Wi-Fi. In addition, the power supply unit consisting of a charging board and batteries provides the required power to the different components.

The NodeMCU ESP32 has a dual core providing the functionality of multi-tasking. Data obtained from ultrasonic sensors 1 and 2 and touch sensing pin is processed on the 1st core of the NodeMCU. The output is provided to the user via the connected buzzer. Data from ultrasonic sensors 3 and 4, push buttons and water sensing pin is obtained on 2nd core of the NodeMCU and is sent to the phone over Wi-Fi for further processing. The flow of data is unidirectional i.e. from components to NodeMCU and NodeMCU to phone.

2) Schematic Diagram

The schematic diagram specifies the positions of the various components used in the construction of the smart walking stick prototype. Ultrasonic sensors 1 and 2 are placed parallel to the ground facing in the forward direction, one near the top and the other close to the ground. Ultrasonic sensors 3 is fixed at an optimal angle to the ground in the forward direction between sensors 1 and 2, while ultrasonic sensor 4 is perpendicular to the ground positioned below sensor 3 in the backward direction. The touch sensing pins are placed under the handle of the stick by which the stick will be held onto by the user. The water sensing pins are placed at the bottom of the stick in contact with the ground. The two push buttons are placed on the handle top for easy access to the visually-impaired user. The buzzer is positioned at the top end of the stick, parallel to the ground and facing in the forward direction. The power supply unit is placed close to the handle. It can be turned on or off using the switch provided.

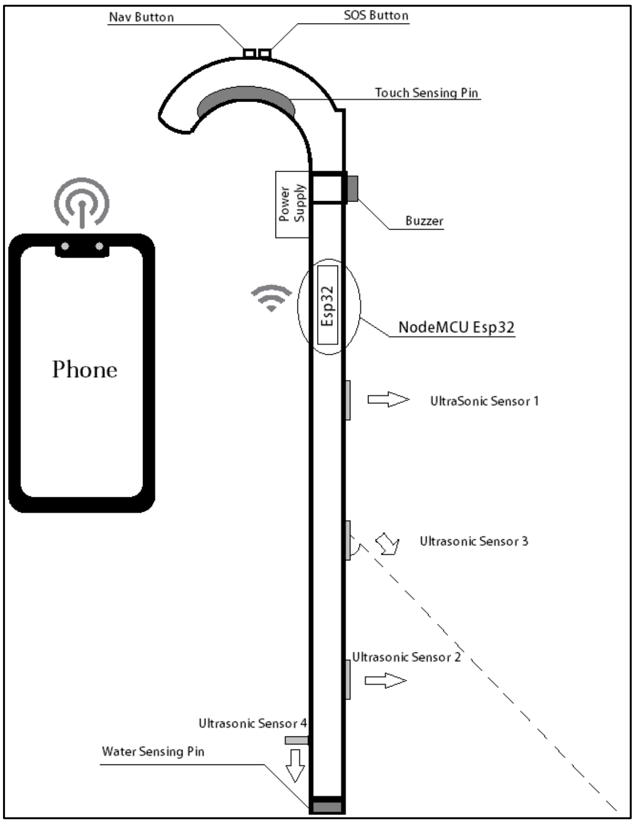

Fig. 2: Schematic Diagram of Smart Walking Stick

B. Flow of Control

Initially, the NodeMCU ESP32 must be connected to the Android phone via Wi-Fi.

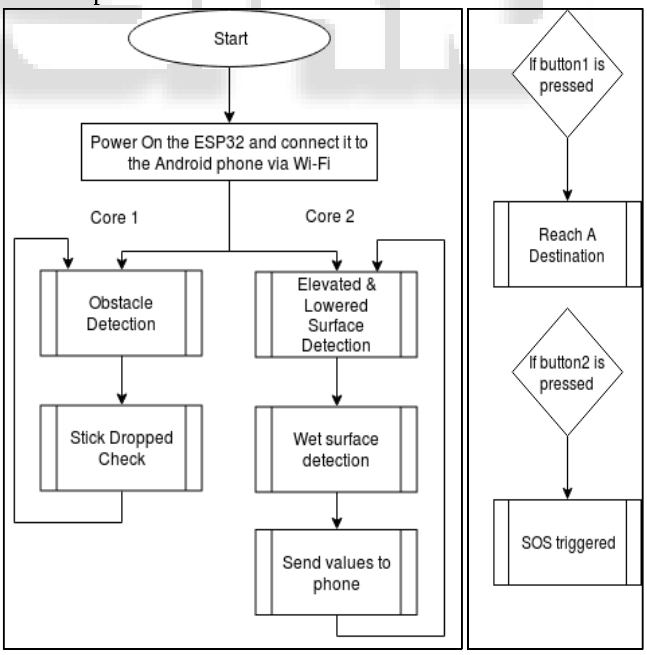

Fig. 3: General Flow Diagram

Once connected, the detection operations will execute as long as the system is switched on. These operations include:

1) Obstacle Detection
2) Elevated and Lowered Surface Detection
3) Wet Surface Detection
4) Stick Dropped Check

Obstacle Detection and Stick Dropped Check operations are carried out on the 1st core of the NodeMCU. Elevated and Lowered Surface Detection and Wet Surface Detection are performed on the 2nd core of the NodeMCU. The data obtained on the 2nd core is sent to the phone for further processing. Buttons 1 and 2 when pressed trigger the Reach a Destination and SOS operations respectively.

IV. CONCLUSION

With the proposed architecture, the visually impaired can enjoy a safe, reliable and convenient way to overcome their locomotion difficulties in daily life without the assistance of other individuals. The developed prototype is user friendly, cost effective, light weight, gives quick results when detecting obstacles, stairs, pits as well as water present in front of the user. The design can be improved before commercial production by implementing some of the following:

- Providing vibratory feedback which will expand the market of users to include even the hearing-impaired.
- Sending user's current location at regular intervals to pre-defined contacts.
- Providing an indication of the battery percentage, especially when running low.

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