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Smart Cane: A Low Cost Assistive Device for the Visually Impaired

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Abstract

Vision impairment or low vision is the disability to see any objects clearly. It might be caused by old age, an accident, or any other neurological condition. People find it difficult to carry out their regular activities, regardless of the cause of their vision impairment or blindness. As medical researchers are working to find a cure for blindness, contrariwise researchers are using technology to make a vision impairment person's life easier in an affordable way. As a result, a smart cane was developed, although it is expensive for most of blind people. The main objective of this paper is to introduce an affordable smart cane for every visually impaired person. The ultrasonic sensors in this walking stick are used to identify impediments. This system is using an arduino to reduce the processing time between receiving and delivering signals created by ultrasonic sensors. The speech output will guide a blind person to take a safe path making the stroll more comfortable and secure.

Keywords: RFID sensor, Smart sensing, Wireless communication, Remote patient monitoring

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1. Introduction

The medical term "visual impairment or VI" is defined when visual acuity is 3/60. There is no specific number of visually impaired people known, but the World Health Organization (WHO) has estimated it at various times. According to the WHO, globally, at least 1 billion people are suffering from severe visual impairment [1]. The WHO also showed in a survey that high income regions have fewer blind people than low-income regions [2]. In sum, in a low-income region, for example, in developing countries, blind people face more challenges in every part of life and feel more miserable.

Visually impaired people's lives are tougher than normal people's. Research conducted by the WHO showed that the most common causes of reduced eyesight are diabetes, trauma to the eyes, age-related macular degeneration, cataracts, infectious diseases of the cornea, and trachoma [3]. An estimation shows that about 596 million people worldwide were living with a distant eye condition that was caused by cataract, glaucoma, or diabetes-related eye complications in 2020. Surprisingly, 43 million people were estimated to be visually impaired [4]. Although it is possible in most cases to prevent blindness, for this to happen it needs treatment promptly, which is highly expensive for people in developing countries.

The impact of vision impairment has two sides: personal impact and economic impact. A visually impaired person suffers from a higher rate of depression and anxiety. Not only that, they have a lower rate of work-force participation and productivity because of their blindness. On the other hand, economically, the annual productivity losses are estimated at 244 billion US dollars globally [5]. Therefore, researchers are trying to invent an affordable and effective system that will help a blind person to complete his/her daily activities without asking for any help from others and will increase the possibility of active work-force

participation. The transition from a traditional cane to a smart cane is eventually innovated. As commercial canes are expensive, we have invented a cost-effective and affordable smart cane which is going to be the subject of this paper.

2. Related Work

Technology makes people's lives easier. Therefore, around the world, all the engineers, medical professionals, and researchers are trying their best to make a difference not only for physically fit people but also for physically disabled people. Vision impairment is one of the top physical disabilities for many people. As technology grows, there are many devices implemented to help blind people; for example, smart cane, ultra cane, guidecane, navbelt, etc [6]. The guidecane is a cane that is shorter than a white cane and can detect immediate obstacles for a blind person [7]. Although it is shorter, it is heavier and has a wheel with a servo motor and ten ultrasonic sensors.

There is a built-in computer connected to the sensors and mini joystick on top of the stick, which gives the user the freedom to choose direction. The ten ultrasonic sensors facilitate the cane to detect 120 degrees of coverage to detect obstacles. When the sensors spot any hurdles, computers calculate the date and create a physical force to warn users and find an alternative path to avoid the disturbances. The GuideCane was implemented by the concept of a guide dog. A trained guide dog is very helpful for a blind person, but it is expensive. According to The New York Times, at present, a trained dog costs between $45000 and $60000, which is almost impossible to afford for many people [8]. Therefore, the guidecane was invented, but it needs more developments such as sensors, wheels, fast detection, voice support, navigation etc.

Nav-belt is a sophisticated computerized Electronic Travel Aid (ETA) for blind and visually impaired individuals, introduced in the late 1990s [9]. The nav-belt is upgraded tech for blind people. A nav-belt is made of a combination of three parts: a waist belt, a portable computer, and ultrasonic sensors [10]. The sensors detect obstacles in the environment and send the signals to the portable computer. The computer analyzes the data and creates a high-pitched noise in the stereophonic headphone. The volume of the sound gets higher when the obstacles get nearer. As the nav-belt has to be worn at the waist, the sensors connected to the belt get a 120-degree view and also have a satisfactory height from the ground.

As a result, it can calculate the obstacle more accurately than a GuideCane. Nav-belt has no guidance mode, hence a vision impaired person can easily achieve the walking speed of a normal human being which is from 0.6 m/s to 0.9 m/s [11]. Though the nav-belt is good in detecting obstacles and creating stereo imaging through sound in the user's mind, it is a prototype and heavy. Consequently, it has less popularity among blind people. In the year of 2022, the most popular and advanced invention for visually impaired people is ultracane. The ultracane started its journey in the year of 2010 and gradually updated its function [12]. Ultracane uses a microcontroller embedded system using these two important parts - i) ultrasonic sensors and ii) infrared sensors [13].Ultrasonic sensors transmit or receive the ultrasonic signal to metering the distance from 2 to 400 cm.

In addition, the infrared sensors detect small obstacles and send signals to the IR transmitter. When the sensors receive signals, it starts to analyze data and if any disturbances are created by the environment, it starts vibrating, which is installed on the handle of the cane. The ultra-cane can detect head-height obstacles, which helps a blind person to travel freely. The vibration due to obstacles also helps to create a mind map in the user's head. As a result, the movement of users becomes convenient and easy. Ultracane is a convenient technology for blind people, but many people cannot afford it. It is very expensive and not available around the world.

3. Motivation and Contributions

Previous data showed a numerous number of people are inactive in social developments because of blindness. Hence researchers are searching for an innovative and effective way to involve visually impaired people in society's development like a physically fit person. For a blind person it is challenging to do any work without seeing and, to measure any obstacles they depend on their instincts such as noise, touch. Researchers are using technologies to sharpen a blind person's instincts to detect hindrance accurately.

The guidecane technology was a ten ultrasonic sensors which could detect 120 degree angles obstacles. But it is inconvenient for a user because it cannot detect chest level obstacles. Additionally, it is very heavy to carry. Another technology- navbelt was invented by a group of researchers to make a travel tool wherein a user can travel easily. This technology was more advanced than guidecane because it can calculate chest level obstacles. Nevertheless it is heavy and makes a noise through headphones wherein a person blind and deaf cannot detect the obstacles. The most advanced invention for users is ultracane which can detect head-high obstacles and is easy to carry. However, it only alerts users through vibration.

We have implemented this system after researching previous technologies to make our cane user-effective. The proposed system can detect chest-level obstacles using ultrasonic sensors, easy to carry. It has water level sensors which will detect water obstacles such as slippery roads by water or snow. It also has a remote control system to detect the cane's location by initiating a buzzer. As output, we have used earphones to give the user a voice controlled navigation, vibration system if the user is not only visually impaired but also unable to hear.

4. Design and Development

The development of our proposed smart cane idea design in our university lab. The implementation of this smart cane

project was split into two parts: hardware and software. Both will be highlighted in the following paragraphs:

4.1 Conceptual Design:

This smart cane can identify impediments in both dry and wet situations. Rain, for example, is a typical meteorological occurrence in Asia, making life more difficult for visually impaired people. While ultra-cane cannot identify liquid barriers, we have included a liquid sensor in smart cane, which will detect liquid/water-based routes as well as manholes and other obstructions. In our smartcane system, we employ voice command technology; when the smartcane detects an obstruction or water/liquid, it issues a voice command informing the user that there is an impediment in front of him/her. Furthermore, we integrate vibration technology for deaf people in this system, and our smartcane may be used by both blind and deaf people. When our smart cane detects a stumbling block, it can vibrate the deaf-blind person or person using it. We also offer a remote system for blind persons so that they can easily locate the cane without assistance.

This design will be enabled by pressing the power button. A liquid sensor, ultrasonic sensor, RF transmitter, buzzer, and microcontroller are all used in this system. When the microcontroller is turned on, it begins to evaluate the data received from several sensors and sends the results to the user through vibrator motor, speech output, and buzzing the buzzer. The user may easily locate the cane by using a remote control. The remote control will activate the RF transmitter in the cane and send a signal to the microcontroller, which will activate the buzzer, allowing the user to locate the cane. The SD card module is for backup to store data for microcontroller through sonar sensors, liquid level sensors or RF transmitter.

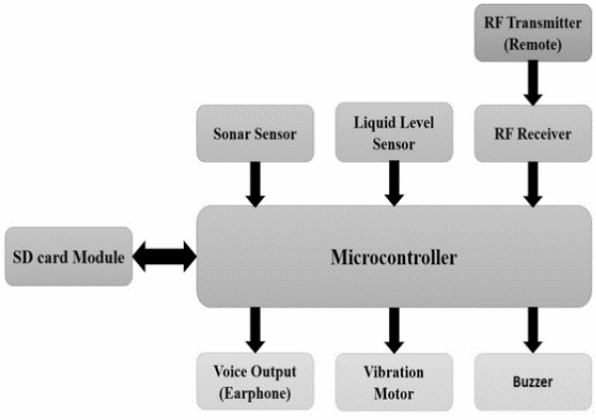

Figure 1. Hardware schematic of the system

4.2 Hardware Elements:

The proposed operational method of the smart cane can be seen in the figure-1 of the suggested system's hardware schematic. The Arduino Uno, RF 315MHz 4 Channel Wireless Remote-Control Module, RC260 micro vibration motor, Liquid level sensor, HCSR04 ultrasonic sensor, Micro SD Card Module, LM2596 Buck Converter, Battery 12V, and YL-44 Buzzer are the main pieces of hardware required to build this system. Other minor components utilized in this system are a breadboard, connecting wires, resistor, and female audio jack (3.5 mm).

5. Implementation

In the proposed system, an Arduino uno-R3 has been used to control the entire project based on the microcontroller ATMega328. It has 14 digital input and output pins, of which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. The circuit conceptual design of this system is very simple. The complete circuit connection diagram is given below.

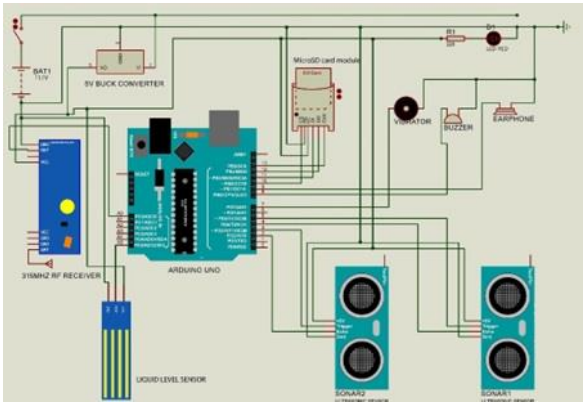

Figure 2. Circuit diagram of the system

Two ultrasonic sensors named sonar 1 and sonar 2's echo and trigger switch are connected to the Arduino pin 2 to pin 5. The ultrasonic sensor receives the signal from the Arduino and takes the distance of an object as input and sends feedback to the Arduino through pins 2, 3, and 4, which activates the vibration motor and voice output in the earphones.

The liquid level sensor helps to identify the water holes for visually impaired people in this system. The Waveshare liquid level sensor has 3 pins: GND, VCC, and AOUT (Analog Output). The GND and the VCC pins of the module are connected to the GND and the 5V pins in the Arduino, respectively, and the AOUT pin to A5 (Analog pin) in the Arduino Uno R3. The liquid level sensor operates while the current is high enough to conduct between the base and the positive power supply, so a certain amount of current is

generated between the base and the emitter. The produced amount of current creates the amplification factor between the collector and the emitter and induces a voltage in the connected buck converter, which sends a signal to the Arduino for data analysis.

Another important part of this system is the 315Mhz RF 4 Channel Receiver Module. The 315Mhz RF receiver has 7 pins—3 GND, 2 VCC, AOUT, and an ANT pin. The RF 315MHz receiver's output pin is connected to the Arduino's A0 pin. Initially, the transmitter draws no power when transmitting logic is zero. Therefore, the user needs to press the remote button to turn the logic zero to one to send data serially from the transmitter to the tuned receiver via ANT pin (antenna). When logic is one, the transmitter gets power from the power supply through the VCC pin and gets high, thus sending a signal through the output pin to the Arduino and activating the buzzer to locate the smart cane for the user.

The user needs to press the power button to turn on the smart cane, which will activate multiple sensors to take data input from those sensors and send it to the microcontroller for analysis. According to the data, the microcontroller will give output to its user through voice output, a buzzer and a vibration motor.

6. Key Features of the System

The proposed low-cost smart cane system is based on two basic principles: the first is that it should be affordable to individuals in all nations, developed, developing, and impoverished. Another goal is to assist visually impaired persons in becoming more self-sufficient. As a result, the essential features are organized around these concepts and described further.

The main purpose of this smart cane is to detect obstacles fast and guide the user accordingly, so that they can avoid obstacles effectively. In this smart cane, two ultrasonic sensors are installed to detect manholes and other obstacles. At first, powering up the cane will help it collect information from the environment and analyze that information according to the user's convenience.

The ultrasonic sensor has two main parts: a transducer which creates ultrasonic sound and the other part collects its echo. It calculates obstacles' location and guides the user left, right or any suitable direction. The two ultrasonic sensors are able to detect chest-level obstacles and manholes from a minimum range of distance and send this data to the user through voice out or the vibration motor.

Water Detection

The ultrasonic sensors can detect any solid obstacles very efficiently, although it is not efficient to detect water obstacles, which is very inconvenient for users. Hence, in this system, a water level sensor is used to eliminate this problem. The water level sensor is installed at the bottom of the cane. When it comes in contact with water, it sends data to the Arduino and turns on the buzzer and vibration motor to alert the user.

Figure 3. Testing the smart cane

Remote controlled Location Finder

In this system, a remote-controlled location detector is used to locate the smart cane position. The user can easily locate his/her smart cane by just pressing the remote. The remote will activate the buzzer and vibration motor, which will help the user measure the distance and direction of the smart cane.

Multiple output/assistance System

The project has created a variety of outputs, including voice output through earphones, a buzzer, and vibration on the cane. A voice output will guide the user by sending obstacles' distance, position, and type, and also a blind or deaf user will get vibration output from the cane. The vibration motor will guide the user to avoid all types of obstacles. The vibration will be high if the obstacle is nearer; it will be low if the hindrance is at a minimum distance.

7. Experimental Evaluation and Cost Analysis

The user will be guided by a speech output that sends the distance, position, and kind of obstacles, and a blind or deaf user will get vibration output from the cane. The user will be guided by the vibration motor to avoid all forms of obstructions. If the impediment is close, the vibration will be considerable; if the obstruction is far away, the vibration will be low.

The system has conducted a study on 20 users (blind people) to get real feedback on its effectiveness, user experience, and functionality. The system has got positive feedback from most of the users. However, the system has 10% negative feedback. The user advises us to slow down the voice frequency as it will be helpful for old people. In addition, we are working on it to set a GPS tracker so that we can connect with Bluetooth or Wi-Fi, which can be done in the future to make this smart walking cane the most efficient and effective tool for visually impaired people.

Figure 3. Testing the smart cane

The most important question now-why is the smart cane affordable? Looking at the hardware elements-each of them are cut-rate products. To make this cane it costs approximately 60 USD while an ultracane is costing a minimum 634 USD. Table I is showing each product's price from amazon.com, ebay.com and aliexpress.com.

Table 1. Cost analysis of the system.

SN	Equipment's Name	Quantity	Price ($)
01	Arduino Uno	1 pcs	19.96
02	RF 315MHz 4 Channel Wireless Remote-Control Module	1 pcs	5.91
03	HCSR04 ultrasonic sensor	2 pcs	1.50
04	RC260 micro vibration motor	1 pcs	6.82
05	Liquid level sensor	1 pcs	3.75
06	Micro SD Card Module	1 pcs	6.69
07	LM2596 Buck Converter	1pcs	1.49
08	Battery DC 12V	1 pcs	4.89
09	YL-44 Buzzer	1 pcs	1.24
10	Breadboard	1 pcs	2.42
11	Connecting wires	50 pcs	1.60
12	Resistors (220 Ohm)	1 pcs	0.20
13	Cane	1 pcs	2.75
Total			59.22

8. Conclusion

The proposed system of smart walking cane tried to eliminate all disadvantages a user can face. This system uses the latest sensor based technology such as ultrasonic sensors, water level sensors, and embedded systems. Notwithstanding, it is a prototype, the system has good user feedback. The cost of this system is easy to bear for users as the system uses simple circuits and the materials are get-at-table. As this smart cane is inexpensive and light-weight, portable, it is possible to manufacture it easily which will make a visually impaired person's life become less challenging, more productive and confident.

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