Smart Cane for Assisting Visually Impaired People

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***Abstract*—Blindness disables a person from self-navigating outside well-known environments. It affects their ability to perform several jobs, duties, and activities. They are dependent on external assistance which can be provided by humans, dogs or special electronic devices for better decision making. This motivated us to create a prototype called "Smart cane for assisting visually impaired people" to overcome the problems they face in their daily life. Our device is a low cost and lightweight system that processes signals and alerts the visually impaired over any obstacle, potholes or water puddles through different beeping patterns. It senses the light intensity of the environment and illuminates the LED accordingly. These are accomplished by incorporating two ultrasonic sensors, a moisture sensor and a LDR sensor along with an Arduino Nano micro-controller. These are placed at specific positions of the cane for efficient guidance. Moreover, a GSM module is also added to the system so that the visually impaired person can send a message to the emergency contact number in case of distress. The developed model showed 89 percent accuracy and 80 percent of the users were satisfied with the developed prototype.**

Keywords:Arduino, LDR, Moisture-Sensor, Ultrasonic sensor, Internet of Things

I. Introduction

The estimated number of Visually Impaired people in the world is 285 million, of which 39 million are blind and 246 million have low vision; 65 percent of people are visually impaired and 82 percent of blind are 50 years and older [1]. Visually impaired people often find it challenging to commute in a public environment unassisted. This is due to irregular terrain, poorly maintained roads with potholes, water puddles, uneven steps cause inconvenience to people with optical disabilities. Apart from the difficulty to commute, another important factor is the cost of treatment. It is very important to provide cost-effective and efficient support with adequate treatment. Conventional methods of guidance for visually challenged are walking cane and guide dogs. With the advancement of technology, we can modify the walking cane to be smart enough to detect obstacles and warn the user. There were several prototypes developed in the past to help the visually challenged [2] [3] [4] [5] [6], many of these prototypes have several drawbacks and limitations. The models developed in [2] and [3] are cost-efficient compared to other prototypes but employ only a single sensor for obstacle detection. The ultrasonic sensor is used to detect obstacles present in front of the user, and cannot detect changes in terrain or detect potholes. Devices that can illustrate the distance of the obstacles present in the path of the user were proposed in [4] and [5]. In [4], the distance of the obstacle can be indicated to the user by different vibration patterns, this would be time-consuming for the user to analyze and understand. The model in [5] uses voice commands as feedback and also employs a water sensor, though another terrain detection method is available but the distress message feature is not available. The smart cane proposed in [6] employs multiple sensors for a wide angle of coverage, and contains a GPS and GSM system to send distress messages, but does not provide methods to detect changes in terrain or detect pothole. Table I shows the existing works and the sensors used.

TABLE I
Comparison Of Existing Smart Blind Canes

S.No	Works	Sensors Used
1	[2] , [3]	Ultrasonic Sensor
2	[4]	Ultrasonic Sensor, Gas Sensor
3	[5]	Ultrasonic Sensor x 2, Water Sensor
4	[6]	Ultrasonic Sensor, GPS, GSM

Some of the key features in the prototypes discussed above for visually impaired which help them to carry out their daily activities are:

- Obstacle Detection
- Pothole Detection
- Distress Messaging(GSM and GPS)
- Gas and Water sensing

To overcome the limitations of existing works, in this paper, we propose a hybrid approach that can detect pothole and obstacle. In addition to this, the device can also detect water puddles and the light intensity of the environment. Here we propose a system that gives a feedback to the user via different buzzing patterns. The user will also be able to send a distress message to the registered number. We built an Arduino-Nano based prototype that has two ultrasonic sensors, a water sensor, an LDR sensor, and a GSM module is interfaced to it. One ultrasonic sensor detects obstacle within the distance of 50cm in front of the user and the other is used to detect potholes. The water sensor at the base of the stick alerts the user with a buzzer sound if the person is about to step into a water puddle. The LDR sensor determines the lighting condition around the user. The LED is turned on if the light intensity is detected to be low. It can also send a distress message to the registered emergency contact when needed. For demonstration, the circuit is built on a breadboard and installed on a blind stick. The proposed project is tested and a survey of user feedback is recorded.

The key contribution of this paper is a smart cane for visually impaired which is a single stick with multiple sensors, Connecting to one sensor network using Arduino Nano micro-controller. The features inculcated in this prototype are as follows:

- Obstacles and Potholes detection: Use of two Ultrasonic sensors, one for detecting obstacles in the straight path of the user and the other for detecting potholes on the ground.
- Puddle detection: A High Sensitivity Water sensor is used to detect puddles on the ground.
- Light intensity detector: An LDR Sensor is used to detect intensity of light and switch on the LED which can be used to alert oncoming commuters.
- Distress Call: A GSM Module is used to send a distress message to a contact of choice in-case of an emergency.
- Testing: Testing the built prototype using different test-cases as well as using a User Feedback form and analyzing the results.

The paper is organized as follows. First we have an Introduction section that addresses the issue at hand, existing implementations and highlights our key contributions to the topic. In Methodology section, we have given a detailed description of the sensors used and the implementation strategy. Results and Analysis section describes the experimental results of the test-cases as well as the User Feedback form. Finally, the Conclusion section summarizes the results with future direction.

II. Methodology

The smart stick extension contains many components, the important ones excluding connectors and boards are:

- Arduino Nano
- Light Dependant Resistor(LDR) Sensor
- Two Ultrasonic sensors
- High Sensitivity Water Sensor
- GSM module SIM900a
- Light Emitting Diode (LED)
- Buzzer

A. Arduino Nano Micro-controller

The Arduino Nano is a micro-controller board based on AT mega38 architecture, which is a single chip micro-controller architecture [7]. Its components consist of 6 analog inputs, 14 digital input/output pins, a reset button, a resonator and holes for attaching the pin headers. It can be connected using a micro USB connection to provide power and micro USB communication to a device.

Although its efficiency is slightly lesser when compared to its predecessor, the Arduino Pro, we have selected the Arduino Nano due to space being such an important factor in this case. Since the sensor network acts as an extension to a blind stick, it must be attached to the stick as an extension. Thus, a smaller board would be more useful to us in this case. Also, since this a supposed to be a cheap alternative, lesser price of the Arduino Nano is also a big factor.

B. Light Dependant Resistor Sensor

The main component of a LDR sensor is the high resistance semiconductor. In low brightness situations, it can have resistance as high as several Mega ohms, while in more brightness, a photoresistor will have resistance as low as a few hundred ohms. If the light incident on the photoresistor exceeds a certain intensity, photons absorbed by the semiconductor give the energy of the bound electrons to jump into the conduction band. The resulting electrons conduct electricity, therefore lowering the resistance for the sensor.

The reason that we use LDR sensor is because of its ability to detect light. In situations of darkness or low visibility, that is, when the light intensity is below 30 candelas, the LDR sensor will be able to detect the presence of the low amount of light and will send a signal, prompting an LED to glow. This will be helpful to oncoming commuters, alerting them that a Visually Impaired person is approaching [8].

```
void LDR()
{
  if(lightintensity < 30)
      digitalWrite(2,HIGH);
    else
      digitalWrite(2,LOW);
    //delay(5);
}
```

The LDR Sensor is connected to a voltage divider circuit and outputs an analog voltage at the controller pin. The analog voltage is read and digitized. A function analogRead() is used to read analog voltage at the controller pin.

C. Ultrasonic Sensor

The ultrasonic sensor consists of a transmitter and a receiver. The transmitter sends an ultrasonic signal of 40 Hz which, if it hits an object which reflects it back, returns and is received by the receiver. The sensor provides the total time of flight of the sound and the distance can be calculated from it [9]. Normally, solid obstacles in the path can be detected the following way: sensor would face the path and continue to give the highest value of time (nothing close enough to reflect the signal) until the sensor experiences an obstacle and provides a shorter time value. In this way, solid obstacles that stick out in an otherwise plain path are detected.

```
    void checkdistance()
{
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
```

```
  duration = pulseIn(echoPin, HIGH);
  distance= duration*0.034/2;
```

The sensor only provides the time of flight of the ultrasonic signal. Therefore calculations must be made to get the distance in centimeters. If the speed of sound in air is denoted as V_{air} m/s and the time of flight of the ultrasonic burst is T seconds, then the distance traveled by the pulse before it hits the obstacle is given by: D = V_{air} * T/2.

```
    void ultrasonic()
{
  Serial.print(distance);
  Serial.println(" Object Alert");
  digitalWrite(buzzer,HIGH);
  for (int i=distance; i>0; i--)
    delay(10);
  digitalWrite(buzzer,LOW);
  for (int i=distance; i>0; i--)
    delay(10);
}
```

Ultrasonic sensors are aligned towards the path in such a way that the signal they emit bounces of the ground right at its critical angle. This results in zero signal coming back to the receiver, thus the sensor provides the highest value of time.

```
    void checkpothole()
{
  digitalWrite(pothole_trig, LOW);
  delayMicroseconds(2);
  digitalWrite(pothole_trig, HIGH);
  delayMicroseconds(10);
  digitalWrite(pothole_trig, LOW);
  pothole_duration = pulseIn(pothole_echo);
  pothole_distance=pothole_duration*0.034/2;
}
```

Now if a pothole is there on the way, the signal travels a bit farther and almost always hits the ground (the side of the pothole) at a bigger angle than the critical angle and thus reflects back to the sensor which outputs a much lower value of time, and thus, detects the pothole [10][11].

D. High Sensitivity Water Sensor

A High Sensitivity Water Sensor is a sensor that is used to detect the presence of water and provides an alert. It relies on the electrical conductivity property of water to complete the circuit between two contacts and decreases the resistance. The device then triggers an audible alarm when the water level has reached enough to bridge the two contacts.

We use a Water sensor on the stick to inform the user of any nearby wet surfaces. When sufficient moisture is detected by the sensor, then it sounds of the buzzer.

```
 void watersensor()
{
  if (percentage>80){
      //Serial.println("buzzing");
      tone(buzzer, 1000); // 1KHz sound
      delay(100);        // ...for 1 sec
      noTone(buzzer);     // Stop sound...
      delay(100);        // ...for 1sec
    }
}
```

When the walking cane comes in contact with deep water, say for example a puddle on the road, the water indicator circuit operates by triggering the base of the switching transistor. When insufficient water, the metal strips are short-circuited by the water triggering a pulse at the base of the transistor, triggering the alarm.

E. GSM Module

```
    void SendMessage()
{
  mySerial.println("AT+CMGF=1");
  delay(1000);
  mySerial.println("AT+CMGS=\"+9199075913);
  delay(1000);
  mySerial.println("There is an emergency!
  Please can you come fast!!!");
  delay(100);
   mySerial.println((char)26);
  delay(1000);
}
```

In case of any emergency, the blind person can press the button installed on the stick. This button enables the GSM. As soon as the message is pressed, a pre-stored message will be sent to the saved emergency contact [12].

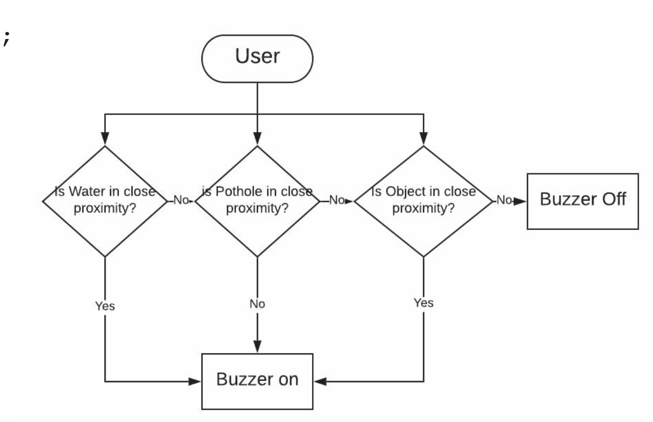

Fig. 1. Flow Diagram

Figure 1 depicts the order of evaluation. The placement of the sensors play an important role. Here we use two Ultrasonic sensors, one for pothole detection and another for obstacle detection. The ultrasonic sensor used for pothole detection is placed at the end of the stick. The Ultrasonic sensor used for the obstacle detection is placed perpendicular to the stick at a distance of (5-10 cm) from the end. The water sensor is placed at the end of the cane. The LDR sensor and LED is placed towards the handle. The button to send distress message is also places towards the handle of the cane. Figure 2 gives a detailed description of circuit.

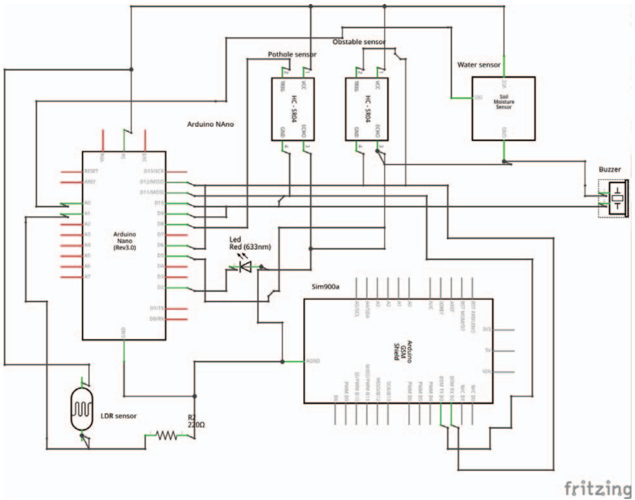

Fig. 2. Circuit Diagram

III. Results and Analysis

Testing for the device as shown in Figure 3 can be carried out by considering a number of use-cases, and further observing whether the device is giving expected output in the situation or not. For each functionality, we considered different test-cases, conducted the experiment and checked if they correspond with expected result.

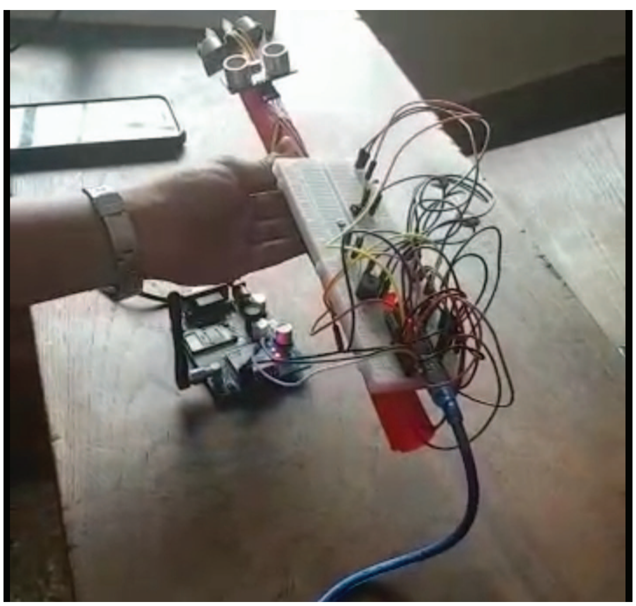

Fig. 3. Picture of prototype

A. Testing for Light Dependant Resistor Sensor

For testing LDR sensor, we considered two test-cases given in Table II. One which takes place in bright conditions, for example under a tube light and one which takes place in dark conditions, for example at night. We then see how the LED reacts.

TABLE II
Testing Cases for LDR Sensor

Test Description	Expected Result	Actual Result	Test Result
Check LDR under bright conditions	LED shouldn't glow	LED doesn't glow	Pass
Check LDR under dark conditions	LED should glow	LED glows	Pass

B. Testing for Ultrasonic sensor

For testing Ultrasonic sensor, first we introduced an obstacle in front of the sensor to see if it detects the obstacle or not. Then, we kept increasing the distance between sensor and object to see till what range the obstacle will be detected. The test results are tabulated in Table III. From these results, it can be noted that any object in the user's path can be detected easily up to a distance of 3 meters.

TABLE III
Testing Cases for Ultrasonic Sensor

S.No	Distance in meters	Buzzer
1	0.5055	ON
2	0.6036	ON
3	1.1780	ON
4	1.5732	ON
5	1.8288	ON
6	1.9700	ON
7	2.0076	ON
8	2.8850	ON
9	3.0550	OFF
10	3.7400	OFF

C. Testing for Water Sensor

For testing Water sensor, we considered two test-cases shown in Table IV. One in which sensor is placed in container with extremely less or no water, and one in which which is placed in a container with substantial amount of water. We then see how the Buzzer reacts.

TABLE IV
Testing Cases for Water Sensor

Test Description	Expected Result	Actual Result	Test Result
Place in container with no water	Buzzer should be off	Buzzer is off	Pass
Place in container with 3cm water	Buzzer should be on	Buzzer is on	Pass

Therefore, from the performed tests, it is found out that the Light Dependant Resistor sensor, Ultrasonic sensor and Water Sensor are all preforming their tasks accordingly. When the situation is such that it triggers any one of the sensors, we get the expected output of the Buzzer or the LED.

D. User Feedback

By conducting User Testing, we were able to determine the Usability of our prototype. The testers consisted of blind-folded individuals in the age group of 18-24 years. They were given the prototype and test out the various situations for each sensor. Later, a survey was undertaken for the users' feedback. This survey was designed by following Likert scale [13]. The users specify their agreement or disagreement on a scale based on the intensity of their feeling. The goal of this survey is to understand what the users want and if the device is solving the problems it is expected to solve.

The questions were designed in such a way that each question would help us reach the goal. The questions were selected to estimate user satisfaction as shown in Figure 7 and the responsiveness of the stick which is shown in Figure 6. The question posed in Figure 4 helps us to understand if the sound was misleading and the one in Figure 5 tells us whether the sound of the buzzer was loud enough for the user to hear it.

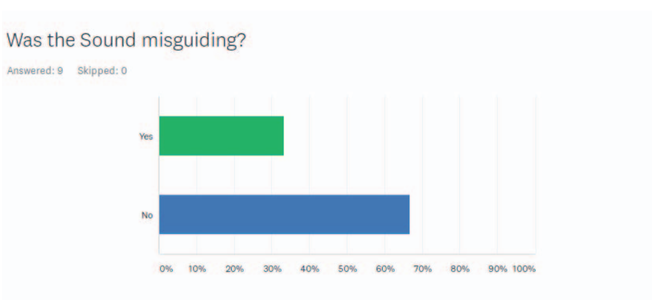

Fig. 4. Survey result 1

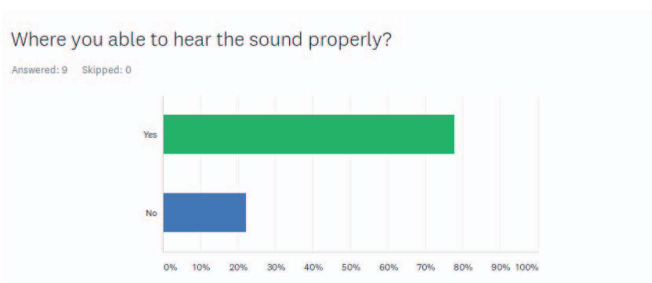

Fig. 5. Survey result 2

In this paper, we mention only a few of the questions posed to the users. An analysis of the results from the Users' Feedback gives us a clear idea about the usability and the users' experience of our prototype. It also gave an idea of how well the different sensors of the sensor network are functioning in a real world setting.

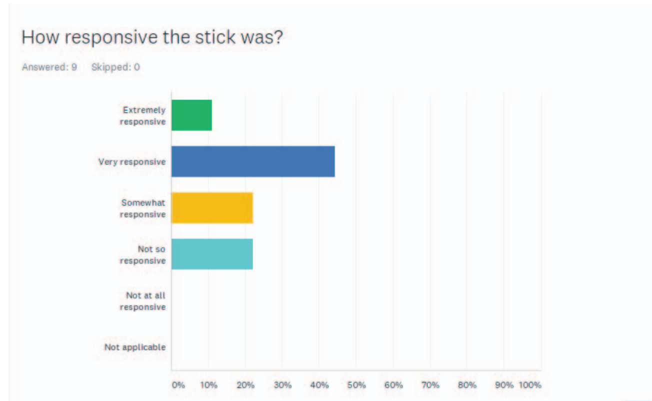

Fig. 6. Survey Result 3

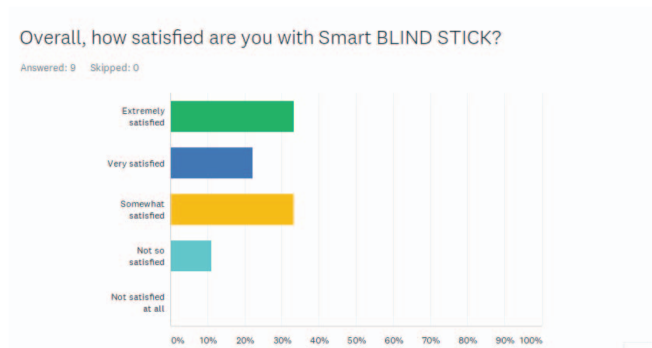

Fig. 7. Survey Result 4

IV. Conclusion and Future Work

Using suitable sensors like Light Dependant Resistor sensor, Water sensor, Ultrasonic sensors and GSM Module, connected to Arduino Nano micro controller, we were able to successfully design and implement a smart cane that can be used by those who are visually impaired when they commute. We were also able to successfully test the device using created test cases.

Further aspects of the system can be improved, by detecting the speed and the type of obstacle approaching. More sensors such as Gas Sensors and Temperature sensors can also be added to the sensor network. Also in the near future, a global positioning method to find the position of the person using the GPS and GSM to communicate the location to the emergency contact can also be devised.

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