

Ultrasonic Sensor based Smart Cap as Electronic Travel Aid for Blind People

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Abstract—Vision is a beautiful gift to humans. This paper aims to develop an ultrasonic sensor based smart cap prototype as an electronic travel aid for blind people that can help them travel independently. The smart cap consists of ATmega microcontroller, Arduino board, three ultrasonic sensors, and a buzzer. Simulation of the system is provided for understanding the concept and to check its functioning. Proteus 8 simulation environment has been used for this purpose. Smart cap is a closed loop control system that continuously monitors the presence of any object around it and feedbacks the output to input for comparison. Finally, a step by step process of hardware connections has been provided.

Keywords— Blindness, ultrasonic sensor, electronic travel aid, closed loop control system, smart cap

I. INTRODUCTION

As per the World Health Organization, 2.2 billion people have a vision impairment or blindness, globally [1, 2]. Broadly, blindness can be categorized as two types, they are full blind and partially blind. Partially blind people can see partially or suffering from any other eye diseases, which create vision issue. The partial blindness is the result of weakened optical nerves, and full blindness is the result for the permanent damage of vision. One can imagine the full blindness by blindfolding her eyes. Nothing can be seen in that condition, and it became tough to move. A blind needs a person or helping aid to guide the directions. Generally, the white cane is used as helping aid by blind people. In a familiar travelling area and environment, the white cane mostly solves the purpose. In an unfamiliar environment, the person may get confused and may need a better helping aid for guidance.

Many people suffer from problems of vision has undergone a challenge in travelling independently. According to the needs of people, there are many tools to help their mobility. One of the techniques is to train them by an expert to walk independently [3-5]. But the training is too costly, and everyone can't afford it. Another method is to train a dog that can help people to show the path. But training the dog is itself a costly affair. Moreover, the extra burden of taking care of dog will make it a challenging task[6-8]. Life of the dog is short and is limited to 10 years only. All of these makes these method complex and costly.

Recently, many new technologies have been developed to take care of the mobility of blind people. These mainly include electronic devices, sensors, and signal processors [9-15]. These are called ETA (Electronic Travel Aid) devices. According to many studies, ETAs are classified into two major types, 1) sensor input, and 2) camera input. These devices operate precisely as a radar system works using ultrasonic rays or similar rays to determine the height,

direction, and speed of the object. The distance of objects and obstacles can be measured by the time of the wave travel.

In this paper, an ETA has been made by connecting three ultrasonic sensors on a cap in the three different directions. Sensors bring all reflective signals and examine the distance of object if present through Arduino microcontroller. In case of presence of any object in the vicinity of sensors found then microcontroller sounds a buzzer to alert the blind person. Further, the use of a cane and other costly tools is not needed. The person can just wear a cap. It is cheap and suitable for real-time applications.

II. COMPONENTS AND THEIR DESCRIPTION

The following components have been used in this project:

1. Arduino UNO (ATmega328p)
2. Ultrasonic sensor
3. Buzzer
4. Cap
5. Wires
6. Battery

These are discussed here briefly.

A. Arduino UNO (ATmega328p)

Arduino Uno board is a 28 pin ATmega328p microcontroller based open-source microcontroller board, developed and coded by Arduino CC. The board contains both analog and digital pins. An Arduino UNO has 14 digital input/output pins in which 6 are PWM pins, 6 analog inputs, a power jack, a USB connector, a reset button. The power supply is given by connecting it to a PC using type B USB cable or by AC to DC adapter, and later by a battery. It can program with Arduino IDE software which is based on C/C++. The UNO differs from all preceding boards, in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the ATmega 8U2 programmed as a USB-to-serial converter. The Arduino UNO microcontroller board is shown in figure 1.

B. Ultrasonic sensor

The ultrasonic sensor, as shown in figure 2 is used to avoid the obstacle. It has a 2-400 cm range for sensing objects. Its accuracy can be up to 3 mm. It includes control, transmitter, and receiver circuit. It sends 40000 Hz signal in the environment and detects whether it returns back or not. The working principle of the ultrasonic sensor is the same as that of the radar system. The ultrasonic sensor has two parts, first is a transmitter, and second is a receiver. Transmitter continuously transmits waves. If any object lies in the path of the wave, then wave strike it and reflect towards the source and received by the receiver. It determines the distance of the

object based on the speed of wave and time taken in transmitting and receiving, as shown in figure 3.

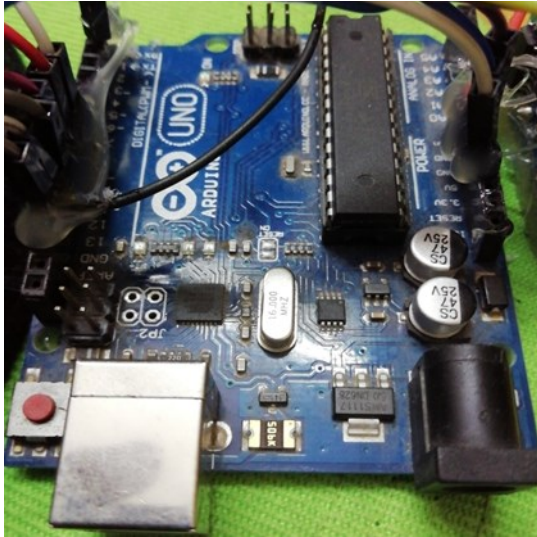


Fig. 1. The Arduino UNO Microcontroller Board.



Fig. 2. An ultrasonic sensor.

It consists of 4 pins, i.e. *vcc*, *trig*, *echo*, and *gnd*, as shown in figure 3. 5 V is applied to *vcc*, and *gnd* is connected to *GND* pin of Arduino or common ground. *trig* and *echo* produce digital signals and are connected to digital pins of Arduino. It is necessary to implement a timing loop in the microcontroller code to measure the time required for the sound wave generated by the transmitter to traverse the distance to the object.

The distance of the object from the sensor can be measured by the time consumption in transmitting and receiving the signal. If transmitter is receiving the signal after striking the object in 10 milliseconds, then the distance of object from the sensor can be calculated as

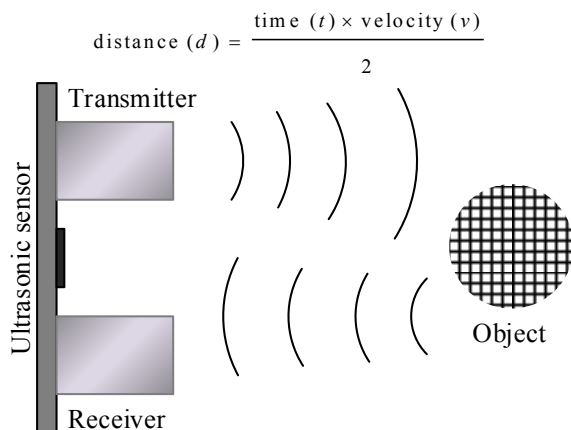


Fig. 3. Working process of an ultrasonic sensor.

Speed of sound is

$$v = 340 \text{ m / s}$$

So

$$\text{distance } (d) = \frac{0.01 \times 340}{2} = 1.7 \text{ m}$$

C. Buzzer

Ultrasonic sensors periodically provide low-frequency signals. Signals travel in the air at a speed of sound. After hitting an object, signals reflect to the source and received by a receiver situated on the sensor. If the object lies within the defined range, then the sensor gives a signal to buzzer using Arduino through the *echo* pin. The magnetic flush disc present in the buzzer attracts the magnetic field. When the oscillation signal moves through the coil, it creates a variable magnetic field that vibrates in a frequency that is equal to the disk signal. The buzzer used in the Smart cap is shown in Fig. 4.

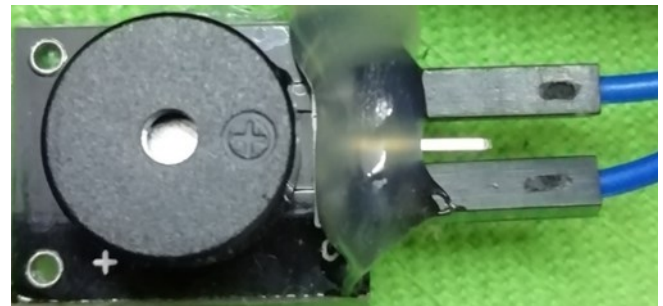


Fig. 4. The buzzer used in the Smart cap prototype.

III. THE SMART CAP

The smart cap works on the lines of a radar system. Three ultrasonic sensors are connected in three different directions on the cap. An ultrasonic sensor has two parts, *trig* and *echo*. The *trig* releases wave and the wave reflects after striking an object and received by the *echo*. The *echo* behaves as a receiver. The three ultrasonic sensors take the reading individually and send it to Arduino, as shown in the block diagram in figure 5. Arduino program calculates the distance of the object from the sensor. As per the program, if the distance is less than 1 m, then the buzzer sounds, and if it is more than 1 m the buzzer remains silent. The distance can be adjusted by modifying the program and keeping it within the range of the sensor.

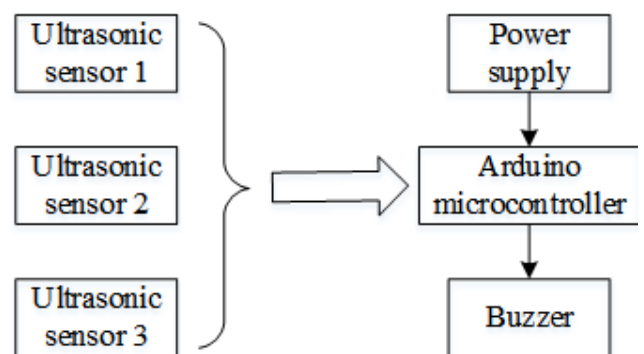


Fig. 5. Block diagram for the Smart Cap.

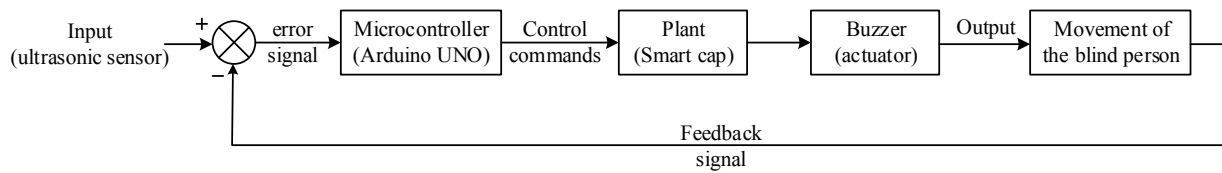


Fig. 6. The closed loop control system of the Smart cap.

Only one buzzer is used in this prototype, and it can produce only one type of sound. It gives rise to the challenge of deciding the direction of the object by a single sound. A delay is provided in buzzer sound to mimic the right direction of the object. For all the three directions, the buzzer sounds with different delay times. With different delay times, the user can understand the correct direction of the object and can act accordingly. Every human has 5 senses. Studies show that if any of the senses is lost, then remaining senses' working capability increases in comparison to the normal condition [16, 17]. This concept works here in recognizing the delay in the buzzer buzzing, and user comprehends directions easily with the buzzer sound delay.

The smart cap is a closed loop control system. The closed loop control system of the smart cap is shown in figure 6. The aim or the output of the system is to guide the blind person for movement. Movement of person is compared with the output of the ultrasonic sensor using an Arduino UNO microcontroller board. The error signal is the difference between them. Arduino generates the control commands based on an error signal. These control commands feed into the plant, which is the cap here and decide to sound the buzzer or not. Based on the buzzer sound, the person again decides its movement. Movement of the person is feedback to compare with the ultrasonic sensor output, and it repeats the whole process. By this closed loop control mechanism, the cap becomes a smart cap.

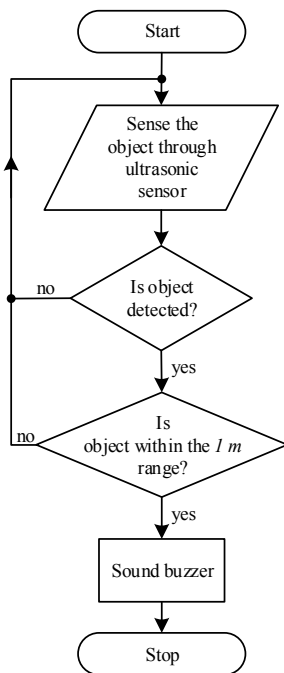


Fig. 1. The flow chart of Smart cap.

Arduino microcontroller sends the commands to sound or not sound the buzzer. These commands are written in Arduino IDE software which is based on C/C++ language. After compiling the commands, these are fed to Arduino UNO. Fig.

17 shows the flow chart of these controlling commands for one ultrasonic sensor. The ultrasonic sensor senses the presence of the objects in their sensing range. If an object is detected, then it calculates the distance of the object, otherwise, continue looking for objects. If the distance of the object is within the 1 m range, then buzzer sounds, otherwise continue looking for objects. The similar controlling process is applicable on other sensors as well. The difference is in the buzzer sound. It sounds with different time delays for different sensors.

IV. SIMULATION OF PROTOTYPE

Proteus 8 has been used for the simulation of the prototype. The simulation circuit is shown in Figure 8. The following processes have been followed to simulate the prototype:

1. Firstly, the library of Arduino and ultrasonic sensors were installed.
2. From pick device window, Arduino, three ultrasonic sensors, three variable resistors, and a buzzer were picked.
3. From the terminal window, seven GND and six V Input were picked.
4. All the devices were connected, as shown in Fig. 8.
5. Using Arduino IDE, the code was verified, and the hex file was generated from the code.
6. By selecting the Arduino board in Proteus, the hex file was uploaded.
7. At last, the simulation was run. Based on simulation output and practical's conducted in the real scenario, the resistance was adjusted for distance requirements and to set the buzzer.

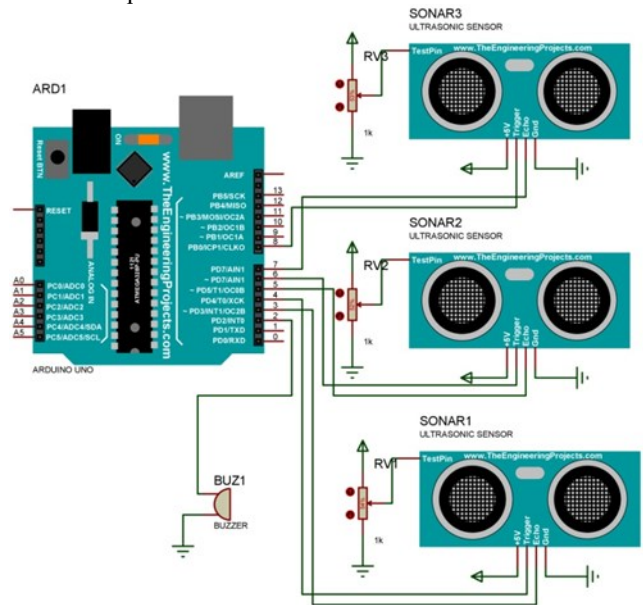


Fig. 8. Simulation circuit of Smart cap. It shows the connections between Arduino UNO named as "ARD1"; three ultrasonic sensors named as "SONAR1", "SONAR2",

and "SONAR3"; three variable resistors named as "RV1", "RV2", and "RV3"; and one buzzer named as "BUZ1".

V. HARDWARE IMPLEMENTATION

In this section, a step by step process of connecting all the hardware components is provided. As mentioned earlier, the components used are one Arduino UNO board, three ultrasonic sensors, one buzzer, one $1\text{ k}\Omega$ resistor, one BC337 transistor, breadboard, USB cable, battery, and connecting wires. Transistor is used for the safe operation of the buzzer. The step by step process of hardware connections are as follows:

- Step 1. Fix all the components on the breadboard, as shown in figure 9.
- Step 2. Make a common bus ground (Bus *GND*) and a common bus positive (Bus *+ve*).
- Step 3. Connect Arduino *GND* to Bus *GND* and its 5 V to Bus *+ve*.
- Step 4. ssConnect the buzzer *neg* terminal to BC337 *C* (collector) terminal.
- Step 5. Connect buzzer *pos* to Bus *+ve*.
- Step 6. Connect BC337 *E* (emitter) terminal to Bus *GND*.
- Step 7. Connect the resistor between BC337 *B* (base) terminal and Arduino 2.
- Step 8. Connect *gnd* of all the ultrasonic sensors to Bus *GND* and their *vcc* to Bus *+ve*.
- Step 9. Connect *echo* and *trig* of first ultrasonic sensor to Arduino 3 and 4, respectively. Similarly, connect *echo* and *trig* of the second ultrasonic sensor to Arduino 5 and 6 respectively and the third ultrasonic sensor to Arduino 7 and 8 respectively.
- Step 10. Connect the USB cable and upload the code in Arduino from Arduino IDE.
- Step 11. Test the operation and troubleshoot if the need arises.
- Step 12. Remove USB and connect the battery for power supply.

Figure 10 shows the final prototype of the Smart cap. All the components are fixed on a cap using a glue. The breadboard has been removed, and components are connected directly to save the space and weight. Arduino *GND* behaves as common Bus *GND* and Arduino 5 V as common Bus *+ve*. Ultrasonic sensors are connected in three different directions, left, right, and front. All the connections are the same as mentioned earlier.

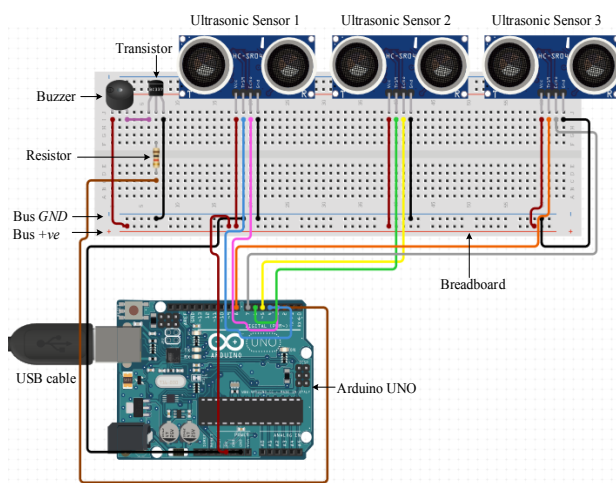
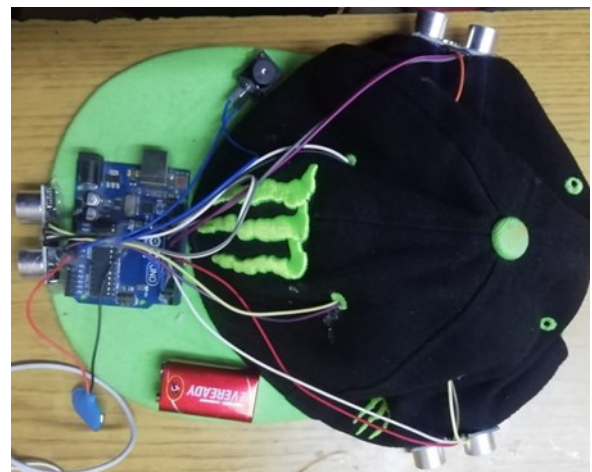


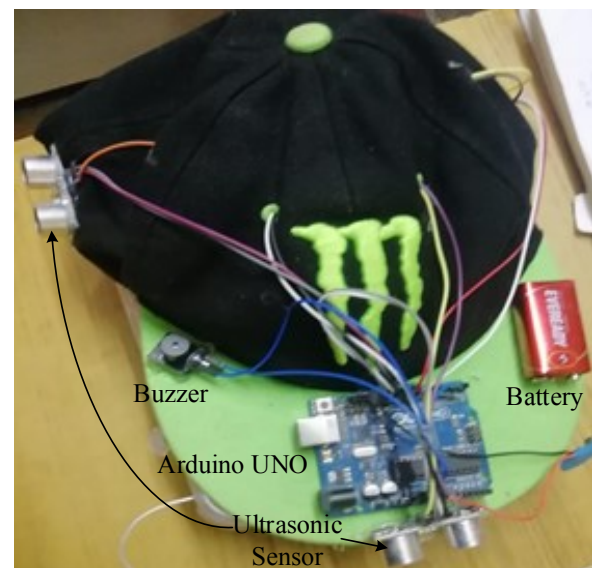
Fig. 9. Hardware connections of different components for making the Smart cap prototype. It shows one Arduino UNO board, three ultrasonic sensors, one buzzer, one $1\text{ k}\Omega$ resistor, one BC337 transistor, breadboard, USB cable, and connecting wires.

VI. RESULTS AND DISCUSSION

The ultrasonic sensor based Smart cap prototype has been developed and tested. Description of main components viz. Arduino UNO, ultrasonic sensor, and buzzer have been discussed briefly. Functioning and controlling of the Smart cap has been shown with the help of block diagram, closed loop control system diagram, and flow chart. Proteus 8 platform based simulation circuit of the system has been provided. A step by step process of connecting all the components has been given in such a manner that anyone can make this prototype. Finally, the hardware prototype has been shown using a commonly available cap with all the components pasted on it. Initial testing of the prototype gave good results.



(a)



(b)

Fig. 10. The final prototype of Smart cap. (a) and (b) show the location of all components from different angles without the use of the breadboard.

There is ample scope of extension of this prototype. The weight of the whole system can be further decreased by choosing other smaller microcontroller and shifting the circuit on a printed circuit board or flexible thin films using fewer wires. Ultrasonic sensor with extended range and less in weight can be chosen. The buzzer can be replaced with small speakers to generate voice commands for directions. Capability to measure the speed of the object can be added. A waterproof or splash-proof system is highly desirable.

More improvements can be made apart from the mentioned above. But each improvement comes with the more complexity and increase in the cost of the system. A breakaway point between cost and capabilities is necessary for mass adoption and commercialization.

VII. CONCLUSION

This prototype is very easy to use, cheap, understandable, and easy to access in daily life to blind people. The prototype has been tested and is approx. 95% accurate in detecting objects. Although the extensive testing of the prototype is not in the preview of this paper, instead it is limited to the design of the prototype. Still, initial testing results were encouraging. Initial testing showed that the prototype was able to identify obstacles in the left, front, and right of the blind person. Being a cap, it also protects the person from the heat in the environment. The focus of this project was to make a cost-effective solution which is achieved indeed. With further modifications in reducing the size and weight of the components, it can be commercialised.

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