Design and Implementation of a Smart Stick for Visually Challenged People

B. Tech Research Project-I Report

by

Hamvir Dev (117EE0353)

Udeshya Dixit (117EE0354)

Shivam Kumar Jha (117EE0362)

Biswas Kashyap (117EE0363)

Under the supervision of

Prof. K. Ratna Subhashini

Department of Electrical Engineering

National Institute of Technology Rourkela

Rourkela-768009

India

April-2021

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Research Project-I report submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Electrical Engineering

National Institute of Technology Rourkela

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Submitted by ____

Hamvir Dev, Udeshya Dixit, Shivam Kumar Jha, Biswas Kashyap

Approved by ____

Prof. K. Ratna Subhashini

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I. Introduction

According to an estimate, there are about 285 million visually impaired people globally. Out of them almost 40 million are blind [1]. In a modern world like ours, there are a lot of problems faced by these visually challenged people. This includes several challenges from day-to-day activities to communicating with others. They face difficulty in interacting with the environment or society due to their inability of making contact with the world using their visual sense organs unlike we normal people do. They have very limited physical movement because they can't properly distinguish hurdles in their way or know how to react in some emergency situations. Though they can rely to some extent on hearing abilities but that seems too risky. For a long time, walking cane and helper dogs have also been of assistance to them. Still, considering a wider picture, many feel difficulties in socializing and feel themselves cut from the mainstream. Even in a digitalized and modern world like ours, there is next to nothing that really helps these people to make their day-to-day routine easy.

I. 1. Aim

The main aim of the project is to use the power of modern technologies like sensors, AI, etc. to make a cost effective and convenient to carry smart stick for the visually impaired that would make their life a lot easier. The stick would sense the environment around and give appropriate instructions to the user to take necessary steps to avoid an accident. As such, they won't feel reluctant interacting with environment and would see themselves socializing with others.

I. 2. Motivation

Though there are few solutions for the same purpose in market like UltraCanne, Isonic, Teletact, etc. but they possess notable disadvantages as mentioned in [2]. They can't detect hidden obstructions like downward stairs, holes etc. Ample training is necessary to help the user understand the feedback signals and to react to them in real time. This can be sometimes tiresome or even expensive [2]. Also, Information transmitted as cracking sound may be embarrassing for the blind person in public. Affordability is also an issue. Thus, our solution will be an alternative to the traditional canes as well as these existing solutions providing faster response, reliability, affordability and a user -friendly experience.

II. Objectives

- To detect static obstacles in the way using sensors
- To detect water lying on the ground, potholes, pits and staircases.
- To warn the user about various obstacles and give directions via an earpiece in enough time for the user to act upon.
- To track user using a GPS module and save various locations in order to assist him/her reach the destination.
- To send a warning message in case of emergency using a GSM module.
- To get an image of the surroundings and obstacles in order to predict various things such as the surrounding is crowded or not.
- To detect objects in the image taken and then use the information to instruct the user.
- To predict the type of surface of the ground if it is smooth or rough.

III. Methodology

The system is equipped with different types of sensors, camera module and Artificial Intelligence techniques. The brain of the system constitutes Raspberry pi and Arduino Nano where all the inputs are processed and decisions are made. There are different types of sensors such as ultrasonic sensors for detecting large and static obstacles, temperature sensor for sensing the surrounding conditions, etc. There are camera modules to take images of the surrounding for processing and for detecting moving obstacles such as vehicles. The images from camera are processed inside the raspberry pi and AI techniques are used for identifying different types of obstacles. The system has GPS module to locate the user and its destination and an audio playback module to guide the user via audio instructions. There is also a GSM module to send a message to saved mobile numbers when prompted by the user in cases of emergency.

The most challenging part of the system is to integrate the individual components into a single system and to process all the inputs to make a decision for the user in a very short time so that user will be able to act upon the situation in enough time to avoid any type of accident. Apart from that we also need to use minimum number of sensors and camera modules in order to reduce the costs and make the system more effective and faster as reducing the number of inputs will lead to faster processing but will affect the accuracy of the system. Hence the utilization of the equipment has to be done in such a manner that accuracy and speed of the system is maintained at the same time. Apart from these things we also need to make the system as user friendly as possible, such as instead of telling the user about obstacles in detail we can just give instructions to the user to avoid that obstacle.

IV. Design of Smart Stick

The system consists of two parts one where Arduino Nano is used for taking input from various sensors and process the information for making decisions whereas the second part has Raspberry Pi with camera module which takes images of the surrounding and object detection is used to make decisions. Overall rough idea of functioning of our proposed system is depicted in Fig.1

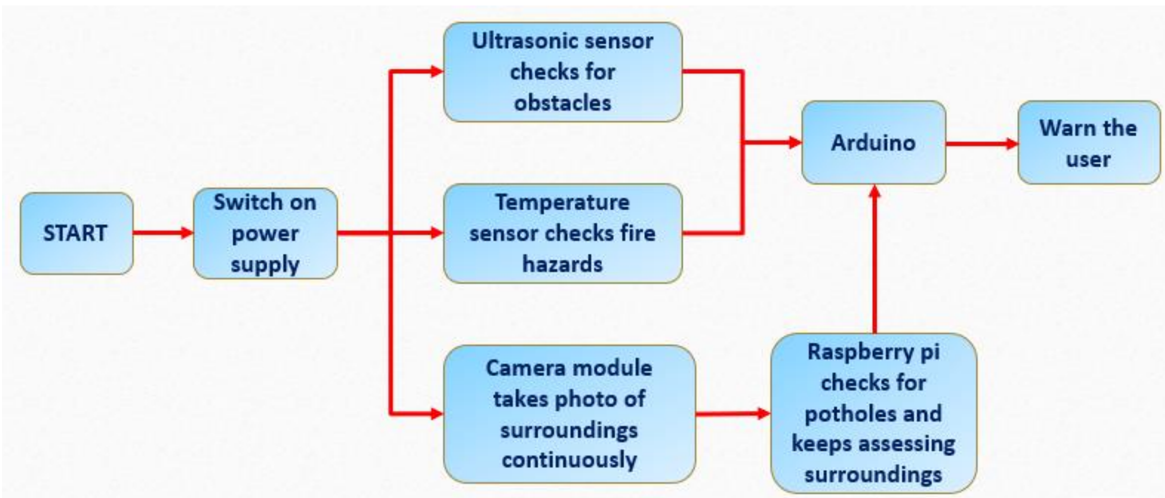


Figure:1 System Flow Chart

IV. 1. Arduino Nano With Sensors

This part basically consists of 3 components: -

1) Temperature Sensor
2) Ultrasonic Sensor
3) Arduino Nano

Temperature Sensor:

It's basic use is to sense the temperature of the surrounding and then warn the user of any fire hazards nearby. Though we have used LM35 here but we can also use thermistors or MWIR infrared cameras to detect fire and alarm the user. It has 3 terminals. 2 for giving supply and ground and third one is for taking output. It senses the temperature of surrounding and gives it as output in form of voltage that can be analog read using Arduino and converted back to temperature using appropriate formulae [3] . We can give it input from 4 to 20V. Generally, the temperature sensor sends back voltage that is directly proportional to the temperature sensed. For instance, LM35 uses 10 mv for each degree rise in centigrade [3]. So if we are using an Arduino to read this voltage (using AnalogRead()) then, we will get some value between 0 to 1024 and we have to convert it back to voltage and then to temperature.

For simple LM35 the conversion formula becomes:

$$T = \left(\frac{x}{1024}\right) * V_{ref}/10$$

Where,

T = temperature in degree Celsius

x = the reading of Arduino through analog input pin.

V_{ref} = Reference voltage of Arduino in mV (5000mV)

Generally, LM35 works over a temperature range of -55℃ to 150℃. The ‘x’ in the equation is the difference of value between output pin and ground pin of LM35, but since gnd pin is connected solidly to ground we can take output pin as output.

Ultrasonic Sensor:

It’s basic use is to sense any obstacle in front and warn the user about any obstacle nearer through a buzzer or speaker. For hardware implementation, we used HC – SR04 sensor.

It has 4 terminals, 2 for supply and ground respectively. Third pin is trigger pin which is an input pin and has to be kept high for 10µs to initialize measurement by sending ultrasonic wave. The fourth pin is echo pin. It is an output pin and this pin becomes high until the sent wave is received back by the sensors. So, if we measure the time for which echo pin remains high then we can measure the distance of the obstacle from the sensors [3]. Its operating voltage is 5v.

Simply,

$$D = S * T/2$$

Where, D = distance

S = speed of sound

T = time taken for wave to return back, called as Time of Flight (TOF)

In Arduino, we have a “pulseIn” function that measures the time T for which echo pin remains high and thus we can find distance from the above formulae. If this distance is less than a certain threshold then we can warn the user. We propose to use 2 sensors facing front, one at the upper position & one at lower position in order to detect both small and large obstacles. We may use an extra sensor for covering wider angle and allowing detection on sideways too. In our design it is powered from 5V output pin of Arduino Nano.

Arduino Nano:

This is the brain of our electronics division. It decides what and which type of hazard is there and whether to alarm the user or not. Its operating voltage is 5V and thus, we can give input in the range of 7 – 21v. It has 8 analog input pins and 14 digital pins that can be used as input or output.

It is interfaced with both ultrasonic sensor and temperature sensor. It takes analog input from temperature sensor using an analog input pin and calculates the temperature of the surrounding from it and decides if the temperature is hazardous [4]. Similarly, it calculates the time for which the echo pin of ultrasonic sensor remains high, which is attached to one of the digital pins on Arduino Nano, and calculates the distance of the user from the obstacle and if the obstacle is nearer enough then it warns the user about the obstacle.

Even the raspberry pi (for object detection using AI techniques) can be interfaced to this Arduino so that without having 2 outputs in our system we will have one output and it will be through this Arduino or the other way round. But we must take care about not overloading this Arduino, so we must give supply to the sensos, in such case, through another battery using buck converter.

IV. 2. Raspberry Pi with Camera Module

We are using Raspberry Pi due to its ability to handle advanced applications like Object Detection [5]. Here an image of the surrounding is taken by the camera module and in the Raspberry Pi, Object Detection is performed using Tensor-flow Object Detection API.

Object Detection:

Object detection is a computer vision technique that works to identify and locate objects within an image or video. Specifically, object detection draws bounding boxes around these detected objects, which allow us to locate where said objects are in (or how they move through) a given scene or frame [7]. It is different from image recognition in the sense that image recognition only performs labelling of an image as shown in Fig.2 & Fig.3.

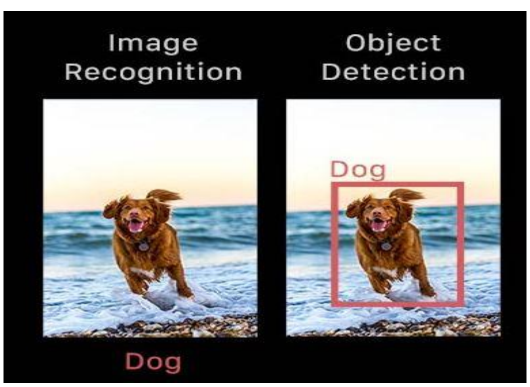


Figure:2 Image recognition and Object Detection [7]

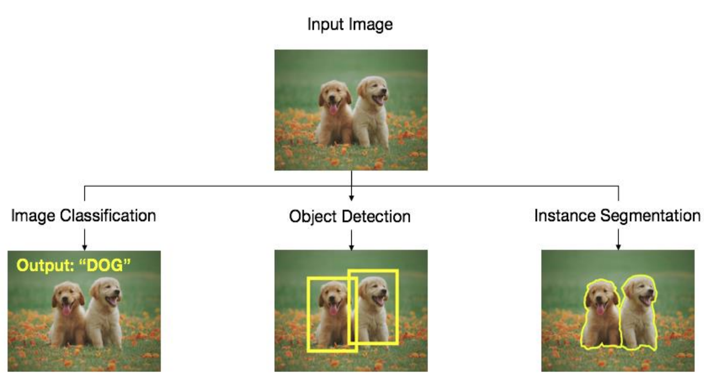


Figure:3 Different Image Processing tasks [8]

We are using Object Detection, as the sensors can only tell us if an obstacle is present or not, their reach is limited and cannot tell what type of object is present whereas with AI based Object Detection we can identify the different objects that are present.

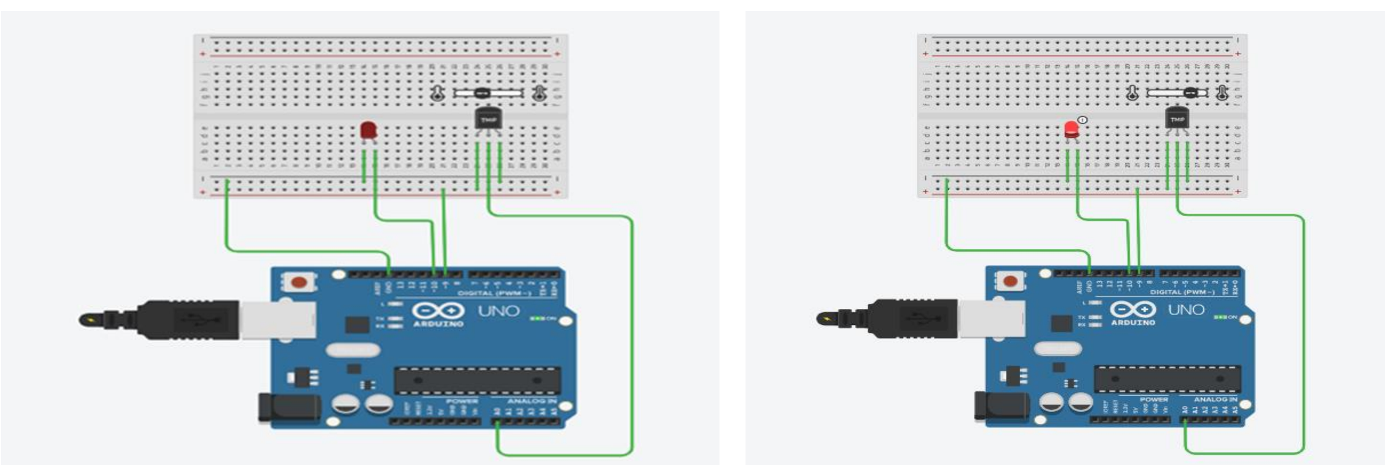
How Object Detection Works:

Deep learning-based object detection models typically have two parts. An encoder takes an image as input and runs it through a series of blocks and layers that learn to extract statistical features used to locate and label objects. Outputs from the encoder are then passed to a decoder, which predicts bounding boxes and labels for each object [6].

Single shot detectors (SSDs) seek a middle ground. Rather than using a subnetwork to propose regions, SSDs rely on a set of predetermined regions. A grid of anchor points is laid over the input image, and at each anchor point, boxes of multiple shapes and sizes serve as regions [7]. For each box at each anchor point, the model outputs a prediction of whether or not an object exists within the region and modifications to the box's location and size to make it fit the object more closely.

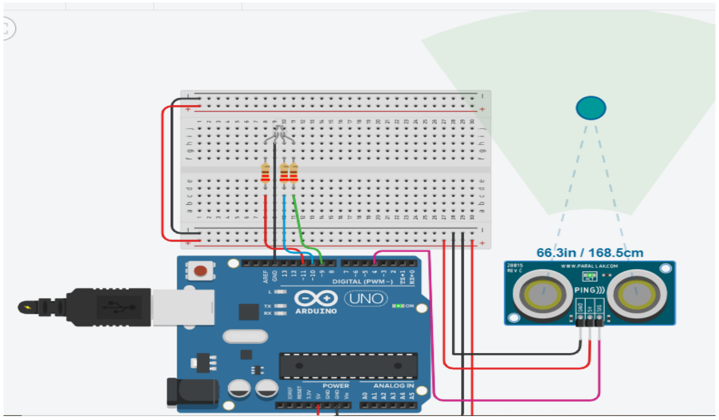
Some popular Deep Learning based Object Detection models are: RCNN, Faster-RCNN, YOLO etc [7]. In the given system we use TensorFlow's Object Detection API which has a pre-trained YOLO based model for making predictions. Raspberry Pi has a script running on it which contains the given API and outputs objects detected by the model [5]. The information is conveyed to the user using methods like Audio Playback.

V. Simulation Results

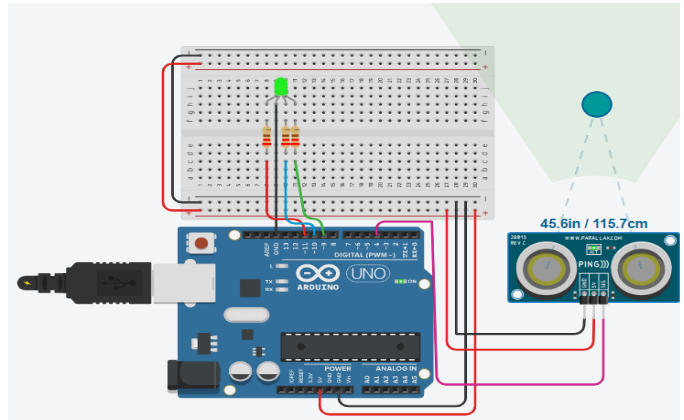


(a) (b)

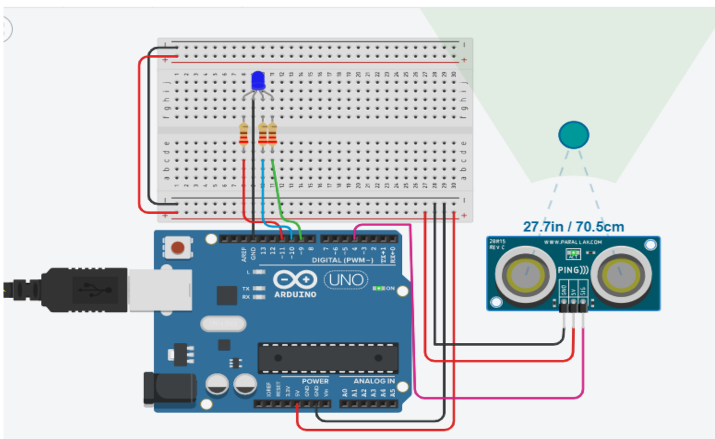
Figure:4- For Temperature Sensor, (a) circuit at normal temperature (b) circuit when temperature is above 50°C. Here Led (output) glows



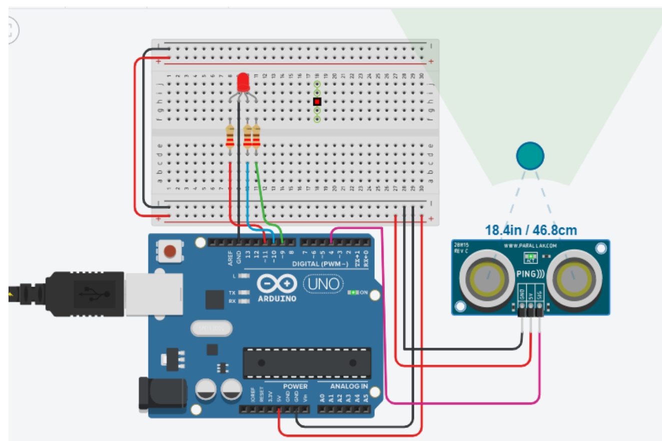
(a)



(b)



(c)



(d)

Figure:5- For Ultrasonic Sensor, (a) LED doesn't glow when obstacle is sufficiently far (b) Obstacle within 1.2m, less intensity output (green LED) (c) Obstacle within 80cms, more intensity output (blue LED) (d) Obstacle within 50cms, highest intensity output (red LED)

VI. Conclusion

A low-cost, reliable, robust smart stick to aid blind people has been proposed. The stick is to be equipped with various sensors as well as Object Detection to help the user. The sensors are to be handled by Arduino and the Object Detection by Raspberry Pi. Data obtained from the sensors and object detection is to be processed to make decisions for the user. A suitable method of guiding the user (such as buzzer or vibration motor or Audio Playback) is required. More features can be added to come up with a more viable and advanced solution (if cost isn't an issue). This constitutes our future work!

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