NAVIGO – AN ARDUINO-POWERED LOCOMOTION ASSISTANCE DEVICE FOR THE VISUALLY IMPAIRED WITH REAL-TIME NAVIGATION ANALYSIS

Spurti Nimbali
spurtinimbali@gmail.com
Delhi Public School R.K. Puram

ABSTRACT

Globally, a staggering 253 million individuals grapple with varying degrees of vision impairment, encompassing 36 million who endure complete blindness. This demographic confronts substantial problems associated with essential aspects of daily mobility, consequently necessitating extended reliance on external caregivers and auxiliary support systems. Challenges pervade fundamental activities, including pedestrian navigation, physical fitness pursuits, and social engagement, thereby curtailing the potential for an autonomous and comfortable existence. The focus of this research is the development and integration of a technologically advanced assistive apparatus, enriched with an impediment identification module, water-level detection and fire detection systems. Upon identification of an obstacle or imminent danger, the system activates real-time auditory and vibratory alerts, thereby enhancing safety and providing critical navigational cues. A series of methodically executed test cases have been conducted to corroborate the efficacy, reliability, and clinical practicality of the proposed device. The findings underscore its robust capacity to significantly enhance the quality of life for the visually impaired, emancipating them from a state of continual dependency and facilitating their pursuit of a more self-reliant and gratifying existence.

Keywords: smart-blind stick, assistive tool, visually impaired, navigation assistance, impedance detection, water-level detection, fire detection, blind stick

1. INTRODUCTION

Visual impairment, a widespread condition characterized by the partial or complete loss of vision, is a matter of profound global significance. With 253 million individuals affected worldwide, of whom 36 million experience complete blindness, the prevalence and impact of visual impairment have far-reaching implications for the affected population and society at large. In 2020, the World Health Organization (WHO) estimated that there were 2.2 billion individuals with visual impairments, of which 1 billion had a condition that has yet to be treated. Furthermore, WHO statistics revealed that, globally, uncorrected refractive errors and cataracts constituted the primary causes of moderate and severe visual impairment, accounting for 53% and 26% of cases, respectively. The International Arrangement of Diseases [1–3] characterizes visual deficiency as a distance vision hindrance that introduces visual keenness more regrettable than 3/60. Those who have the visual acuteness of 6/60 or the horizontal range of the visual field with both eyes open have less than or equal to 20 degrees. These numbers underscore the imperative need to address and ameliorate the challenges faced by the visually impaired population.

People with visual impairment face significant challenges with locomotive activities. They are extensively reliant on the assistance of caregivers and current tools lack to provide real-time assistance. The reliance on caregivers or the utilization of conventional assistive tools, such as the standard white cane, while essential, is far from providing real-time, comprehensive, and intuitive visual assistance. Traditional white canes, a hallmark of assistive technology for the visually impaired, have remained relatively unchanged for decades. While serving as valuable aids for detecting obstacles at ground level, they provide only limited information about the surrounding environment, leaving a significant void in the user's spatial awareness. In essence, these canes offer a basic and tactile means of detecting objects directly in their path but fall short of addressing the broader context that informs mobility, such as identifying upcoming staircases, discerning variations in terrain, or recognizing potential overhead obstructions. Consequently, they do not suffice to address the multifaceted needs of individuals with visual impairments, leading to an enduring reliance on caregivers and limiting the extent of autonomous, convenient, and self-sufficient lives that they can lead.

2. MATERIALS AND METHODS

2.1 PROPOSED SYSTEM

The proposed device is implemented with an impendence detection, water-level detection, staircase and pit detection and fire detection module. The device is powered by an Arduino UNO. It is also equipped with an ultrasonic sensor, moisture sensor and flame sensor.

2.2 SOFTWARE REQUIREMENTS

In this paper, the open-source Arduino Software (IDE) used in which it is easy to write code and upload it to the board. It runs on Windows and Linux. The environment is written in Java and based on Processing and other open-source software. The Arduino Uno microcontroller is an easy to use up till now powerful single-board computer that has gained considerable traction in the hobby and professional market. The Arduino is open source, which means hardware is reasonably priced and development software is free.

2.3 HARDWARE REQUIREMENTS

2.3.1 ARDUINO UNO

The Arduino Uno, a quintessential cornerstone of the Arduino ecosystem, is celebrated as a stalwart microcontroller board that has underpinned countless projects and innovations. Representing the standard by which other microcontrollers are often measured, the Arduino Uno is revered for its comprehensiveness and versatility. This iconic board serves as the entry point for many into the realm of electronics and embedded systems, owing to its user-friendly design and expansive capabilities. It combines the robust ATmega328 microcontroller with a user-friendly USB interface, offering an accessible yet powerful platform for both beginners and experienced developers. The board's extensive compatibility with various shields, sensors, and actuators further underscores its adaptability, making it an exemplary choice for a diverse range of projects.

Logic level: 5V

Input Voltage: 7-12 V

14 digital I/O pins

6 pins providing PWM output capabilities

Output: 40mA per I/O pin

Flash memory: 32KB

SRAM: 2KB

EEPROM: 1KB

Clock speed: 16MHz

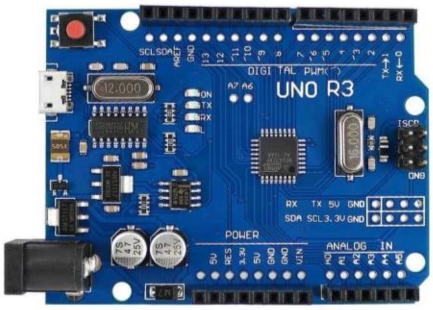

Fig 1: Arduino Uno

2.3.2 ULTRASONIC SENSOR

The HC-SR04 ultrasonic sensor module uses sonar to resolve distance to an object like bats or dolphins do. It offers exceptional non-contact range detection with high precision and stable readings in an easy-to-use package ranging from 2 cm to 400 cm. Its operation is not precious by sunlight or black material like Sharp rangefinders. It comes entire with an ultrasonic transmitter and receiver module. The basic principle of the module is as follows:

i) Using I/O trigger for at least 10 us high-level signal
ii) The Module repeatedly sends eight 40 kHz and detects whether there is a pulse signal back.
iii) If the signal is back, through a high level, the time of high output I/O duration is the time from sending ultrasonic to returning. Test distance = (high level time×velocity of sound (340M/S) / 2)

Fig2: Ultrasonic Sensor

2.3.3 MOISTURE SENSOR

The technical prowess of the Moisture Sensor is evident through its utilization of a capacitive or resistive principle, wherein variations in moisture levels induce changes in electrical conductivity. These fluctuations are meticulously transduced into digital or analog signals, rendering them compatible with a broad spectrum of microcontrollers and data acquisition systems. The sensor exhibits a remarkable degree of sensitivity, allowing it to discern subtle alterations in soil moisture conditions over a wide moisture range.

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Fig3: Moisture Sensor

2.3.4 FLAME SENSOR

The Flame Sensor's technical ingenuity is showcased through its utilization of specialized optical sensors, typically equipped with infrared or ultraviolet detectors, which are highly sensitive to the characteristic emissions of flames. These sensors can discern the unique spectral signatures of flames, distinguishing them from other sources of light or radiation. Additionally, some models incorporate thermal sensors to complement the optical detection, enhancing the reliability and robustness of flame identification.

It typically operates within a specific wavelength range to ensure precise flame discrimination, and it is meticulously designed to respond to rapid changes in ambient light conditions. Sensitivity adjustments and digital interfaces enable seamless integration with various control and alarm systems, while advanced signal processing algorithms contribute to high accuracy and a low false positive rate.

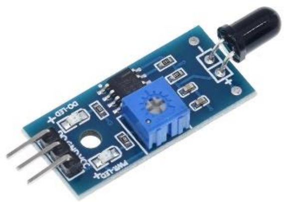

Fig4: Flame Sensor

2.3.5 BUZZER

The piezo buzzer produces sound based on reverse of the piezoelectric effect. The generation of pressure variation or strain by the application of electric potential across a piezoelectric material is the underlying principle. These buzzers can be used alert a user of an event corresponding to a switching action, counter signal or sensor input. They are also used in alarm circuits. The buzzer produces a same noisy sound irrespective of the voltage variation applied to it. It consists of piezo crystals between two conductors. When a potential is applied across these crystals, they push on one conductor and pull on the other. This, push and pull action, results in a sound wave. Most buzzers produce sound in the range of 2 to 4 kHz.

Fig5: Buzzer

2.4 WORKING

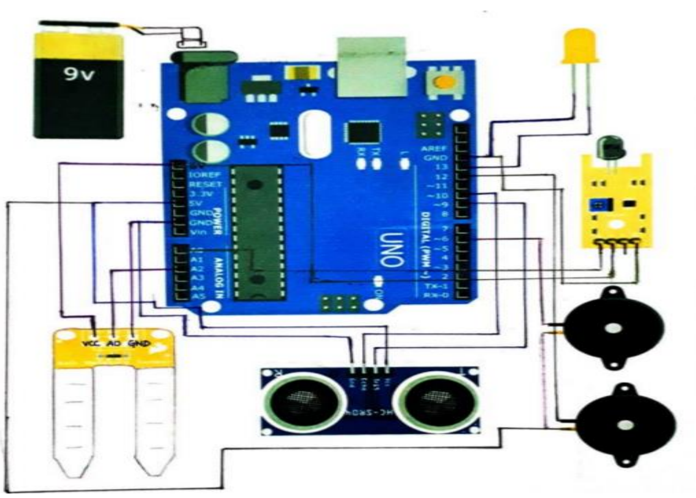

Fig 6: Circuit Diagram

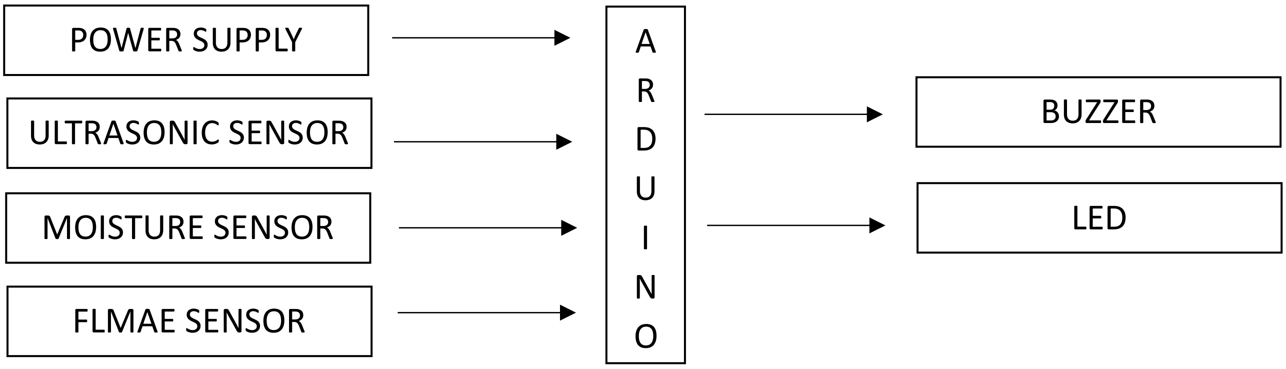

Fig 7: Working Flowchart

```
// defines pins numbers

const int trigPin = 9;
const int echoPin = 10;
const int buzzer = 12;
const int ledPin = 13;
const int buzPin = 6;
const int flamepin=A2;
const int threshold=200;// sets threshold value for flame sensor
int flamesensvalue=0; // initialize flamesensor reading

// defines variables
long duration;
int distance;
int safetyDistance;
```


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// defines variables
long duration;
int distance;
int safetyDistance;
```


```
void loop() {
// Clears the trigPin
digitalWrite(trigPin, LOW);
delayMicroseconds(2);

// Sets the trigPin on HIGH state for 10 micro seconds
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
```

```
// Reads the echoPin, returns the sound wave travel time in microseconds
duration = pulseIn(echoPin, HIGH);

// Calculating the distance
distance= duration*0.034/2;
safetyDistance = distance;
if (safetyDistance <= 25){
  digitalWrite(buzzer, HIGH);
  digitalWrite(ledPin, HIGH);
}
else{
  digitalWrite(buzzer, LOW);
  digitalWrite(ledPin, LOW);
}

// Prints the distance on the Serial Monitor
Serial.print("Distance: ");
Serial.println(distance);

int val = analogRead(A0);
Serial.println(val);
f (val<200) {
  digitalWrite(6,HIGH);
  digitalWrite(13,HIGH);
}

if (val>1000) {
  digitalWrite(6, LOW);
  digitalWrite(13,LOW);
}
flamesensvalue=analogRead(flamepin); // reads analog data from flame sensor
if (flamesensvalue<=threshold) { // compares reading from flame sensor with the threshold value
digitalWrite(ledPin,HIGH); //turns on led and buzzer
digiatlWrite(buzzer,HIGH);
}
else{
digitalWrite(ledPin,LOW); //turns led off led and buzzer
digitalWrite(buzzer,LOW);
}
}
```

The ultrasonic sensor detects obstacles in front of it when under a specified distance range.
This can be calculated by Arduino using the following formula:

Distance = {(Duration/2) / (2/29.1)}
Here, Duration = Echo output; and since we need only oneway distance, hence we divide this duration by 2.
Here the constant 29.1 is derived as follows:

The speed of sound is 343.5 m/s or 0.0345cm/microseconds.
1/0.0345 cm/microseconds is 29.1 microseconds/cm.
Dividing the Duration (ms) by 29.1(microseconds/cm) gives us the distance in (cm).

The moisture sensor and flame sensor also send signals to the microcontroller upon detecting real-time triggers. This information is then processed by the microcontroller which then sends the signal to the output system. The output system consisting of a buzzer generates characteristic alarms to alert the visually impaired. This is paired with an LED to alert nearby bystanders to seek assistance in case of fire.

3. RESULT

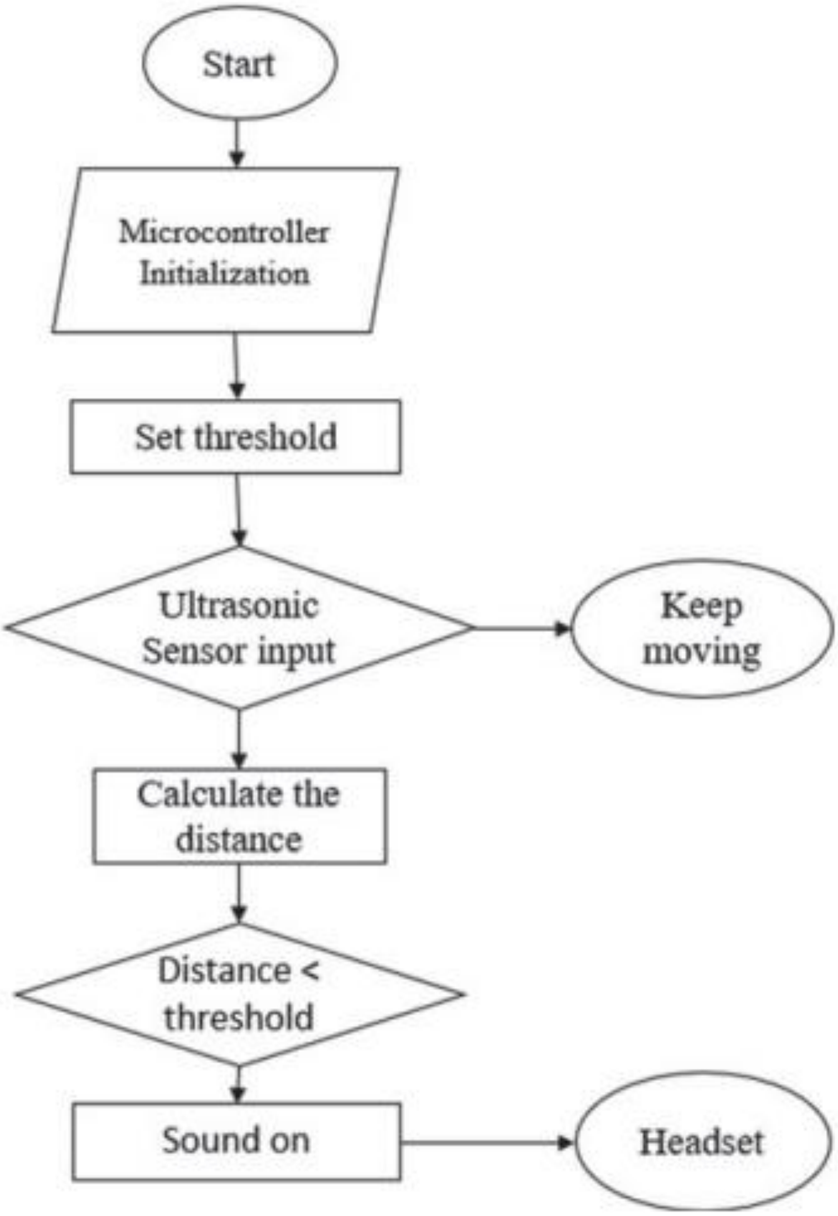

Fig 7: Flowchart of distance analysis

We utilized an ultrasonic sensor, flame sensor and a moisture sensor. These sensors are associated with a buzzer that produces an alarm. To investigate the system's ability, we created hindrances like a divider, a tree, or others on the way. At that point, the ultrasonic recognized the forward checks by computing the distance, The buzzer started to produce sound to caution the blind person, and the notice was established through a headphone. Creating a pseudo environment for testing, we found that the signal produces various sounds in various frequencies. Utilizing those sensors, the stick distinguishes the obstructions which assist the visually impaired in moving securely. In the test case, the water sensor lying at the end of the stick recognized the downpour on the road and functioned accurately to avoid unexpected incidents caused by the water. It created an alarm to express the presence of water. The flame sensor also detected triggers when exposed to nearby flames from a matchstick and lighter. Accuracy is determined in percentage. If the distance increases, then the error values increase. At 30 cm, the error is 0.53, and for 400 cm, the error is 4.17. As distance increases, the accuracy decreases gradually.

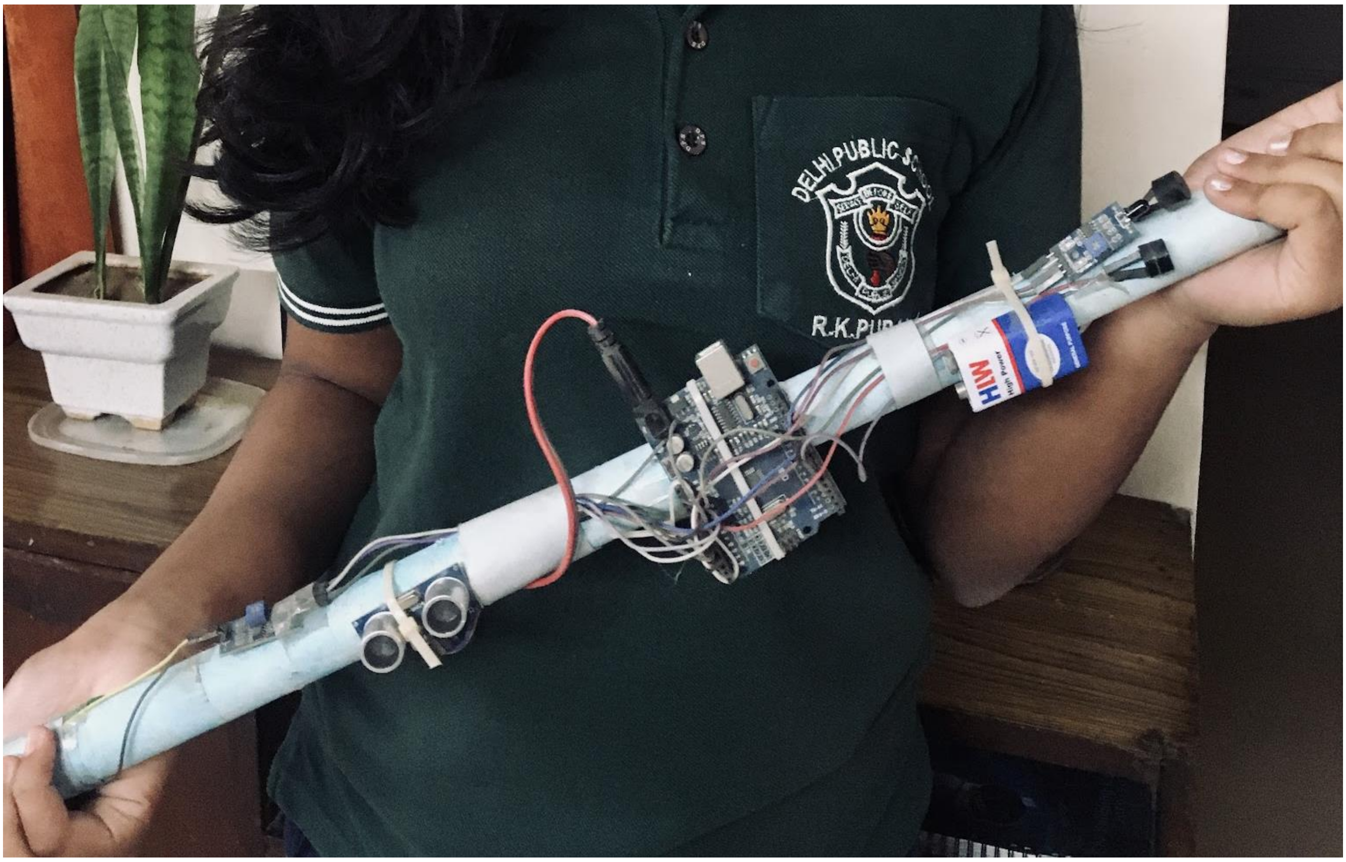

Fig 8: Prototype of proposed tool

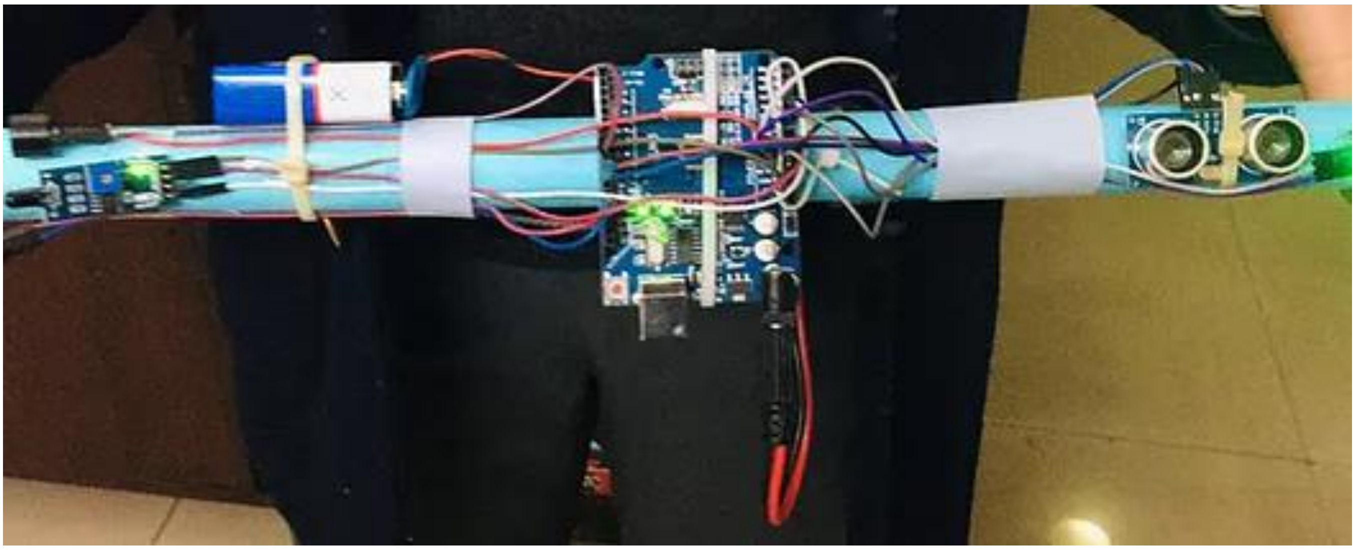

Fig 9: Prototype of proposed tool

4. CONCLUSION

The proposed device is highly efficient and clinically viable. Navigo acts as a basic platform for the coming generation of more aiding devices to help the visually impaired navigate safely both indoors and outdoors. It is highly affordable at a base cost of Rs 1860 ($22.33) and offers a low-cost, reliable, portable, low power consumption and robust solution for navigation with obvious short response time. It leads to good results in detecting the obstacles on the path of the user in a range of 0.5 meters and the moisture and flame detector also showcase promising results and accuracy. Though the system is hard-wired with sensors and other components, it's light in weight, weighing approximately 230 grams. Further aspects of this system can be improved via wireless connectivity between the system components, thus, increasing the range of the ultrasonic sensor and implementing a technology for determining the speed of approaching obstacles. A pit and stair detection module, GPS and GSM system alongside a Machine Learning Object Detection and Recognition model can also be incorporated.

5. REFERENCES

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