# SHADOW SENCE EMERGENCY

**Enhancing Mobility for the Visually Impaired with IoT-Based Audio Alerts**

## A PROJECT REPORT

***submitted by***

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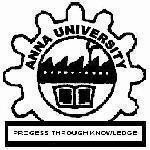
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#### ABSTRACT

This project presents the design and development of a wearable obstacle detection system aimed at enhancing the safety and mobility of visually impaired individuals. The system utilizes an ESP32 microcontroller, ultrasonic sensors, and audio feedback to provide real-time obstacle detection and guidance. Integrated into a cap for comfortable wear, the system uses ultrasonic sensors to detect objects in the user’s path, providing auditory alerts through a Bluetooth-enabled audio system. The alerts are customizable, supporting multiple languages and offering clear, direction-specific guidance.

The system is powered by a lithium-ion battery, with an added solar panel for extended usage, making it a cost-effective and sustainable solution compared to high-end commercial alternatives. The device is lightweight, hands-free, and easy to use, offering an accessible solution for enhancing the independence and safety of visually impaired users in various environments.

Prototype testing has demonstrated reliable obstacle detection with minimal delay, long battery life, and clear audio feedback. While the current system performs well in real-time detection, future improvements are planned to include multi-directional sensing, advanced audio feedback, and mobile app integration for further customization. Ultimately, this project aims to provide a practical and affordable assistive technology solution that promotes greater independence and mobility for visually impaired individuals.

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#### TABLE OF CONTENTS

|  |  |  |
| --- | --- | --- |
| **CHAPT**  **ER No.** | **TITLE** | **PAGE No.** |
|  | **ABSTRACT** | **iii** |
| **1.** | **INTRODUCTION** | **1** |
|  | 1.1 Motivation | **2** |
|  | 1.2 Objectives | **2** |
| **2.** | **LITERATURE REVIEW** | **3** |
|  | 2.1 Existing System | **4** |
|  | 2.1.1 Advantages of the existing system | **4** |
|  | 2.1.2 Drawbacks of the existing system | **4** |
|  | 2.2 Proposed system | **5** |
|  | 2.2.1 Advantages of the proposed system | **5** |
| **3.** | **SYSTEM DESIGN** |  |
|  | 3.1 Development Environment | **6** |
|  | 3.1.1 Hardware Requirements | **6** |
|  | 3.1.2 Software Requirements | **7** |
| **4.** | **PROJECT DESCRIPTION** | **8** |
|  | 4.1 System Architecture | **8** |
|  | 4.2 Methodologies | **9** |
| **5.** | **RESULTS AND DISCUSSION** | **10** |
|  | 5.1 Testing Environment |  |
|  | 5.2 Performance Metrics and Observation |  |
|  | 5.3 key Outcomes |  |
|  | 5.4 Limitations |  |
|  | 5.5 User Feedback Summary |  |
|  | 5.6 Discussion |  |

|  |  |  |
| --- | --- | --- |
| **6.** | **CONCLUSION AND FUTURE WORK** | **11** |
|  | 6.1 Conclusion | **11** |
|  | 6.2 Future Work | **11** |
| **7.** | **APPENDIX** | **12** |
| **8.** | **REFERENCES** | **15** |

**CHAPTER 1**

#### INTRODUCTION

Navigating environments safely poses a daily challenge for individuals with visual impairments, especially in unfamiliar or obstacle-prone settings. Conventional mobility aids such as white canes and guide dogs offer valuable support but are often limited in range and functionality. These tools typically do not detect obstacles above waist height or provide advanced warnings, which can result in accidents or a reduced sense of independence.

Recent technological advancements offer new opportunities to enhance mobility and safety for visually impaired individuals. Wearable devices integrated with sensors and real-time feedback systems can augment traditional aids by providing more detailed environmental awareness. Among these, microcontrollers like the **ESP32**, paired with **ultrasonic sensors** and **Bluetooth-enabled audio feedback**, present a promising foundation for creating smart, accessible, and affordable assistive devices.

This project proposes the development of a **cap-based wearable obstacle detection system** that provides real-time **audio feedback**. It is designed to be **comfortable**, **hands-free**, and **cost-effective**, enhancing everyday navigation while preserving user dignity and independence.

* 1. **Motivation**

**Enhancing Accessibility and Safety:**

The primary motivation is to address the everyday mobility challenges faced by the visually impaired. By providing early warnings about nearby obstacles through audio cues, the system aims to reduce collisions, enhance situational awareness, and improve confidence in movement.

**Limitations of Existing Solutions:**

Current wearable aids, such as vibrating wristbands or clip-on devices, often provide minimal feedback, are expensive, or require specific mounting. Solutions like the OrCam MyEye are high-cost and not suitable for all users, while vibration-only systems lack clarity and user personalization.

**Utilizing Affordable Smart Technologies:**

The availability of low-cost microcontrollers like the ESP32, along with ultrasonic sensors, Bluetooth audio modules, and mobile app connectivity, opens the door to creating an effective and accessible assistive device. This project aims to harness these technologies to create a compact, multilingual, and user-friendly solution.

**1.2 Objectives**

* **Design a Cap-Based Wearable Detection System:**

Design and implement a wearable system that incorporates an ultrasonic sensor into a cap to detect both nearby and distant obstacles, providing real-time audio feedback to the user.

* **Utilize ESP32 Microcontroller for Control and Communication:**

Leverage the ESP32’s Bluetooth capabilities to connect wirelessly with audio headsets and allow smartphone integration for configuration and language selection.

* **Provide Multilingual Audio Feedback:**

Implement a system capable of providing clear voice alerts in multiple languages, increasing accessibility and user comfort.

* **Ensure Cost-Effectiveness and Battery Efficiency:**

Use affordable hardware components and implement low-power modes such as deep sleep in the ESP32 to ensure long battery life and reduce maintenance needs.

* **Develop a Companion Smartphone Application:**

Enable users or caregivers to configure audio preferences, language selection, and obstacle sensitivity settings through a simple, user-friendly app interface.

**CHAPTER 2**

#### LITERATURE REVIEW

In recent years, the development of assistive technologies for visually impaired individuals has gained considerable attention. With advancements in embedded systems, microcontrollers, sensor technologies, and IoT integration, several wearable obstacle detection systems have emerged. These aim to enhance the safety and independence of users by offering real-time feedback on nearby obstacles. The following section reviews relevant existing research and commercial solutions in this domain.

##### [1] Ultrasonic Obstacle Detection System for the Visually Impaired Using Arduino

This paper presents a basic wearable system using an Arduino microcontroller and ultrasonic sensors mounted. The system provides beeping sounds based on the distance to an obstacle. While it serves as a low-cost proof of concept, it lacks customizable feedback, language support, and discreet form factor, limiting user comfort and social acceptance.

**[2] Smart Cane Using IoT and GPS for Visually Impaired Individuals**

This research combines ultrasonic sensors, GPS, and IoT modules in a smart walking cane. It enables real-time location tracking and obstacle detection with vibration and audio cues. Though effective in open areas, it requires the user to carry the cane at all times and does not offer flexibility in how feedback is delivered.

**[3] Development of a Wearable Haptic Device for the Visually Impaired**

This study explores wearable haptic feedback systems using vibration motors placed on the body to indicate obstacle proximity. While vibration is useful in silent environments, the system does not provide descriptive audio messages or language options, reducing its clarity and adaptability for users in different settings.

**[4]Voice Navigation System for Visually Impaired People Using Machine Learning**

This approach applies voice recognition and object detection using machine learning to guide users in indoor environments. Though technically advanced, it depends heavily on cameras and high computational power, making it less cost-effective and harder to scale for wearable use in daily outdoor environments.

**[5] Comparative Analysis of Assistive Wearables for the Blind**

This literature review evaluates several commercial products like OrCam MyEye, Sunu Band, and BuzzClip. The study notes that while these devices offer useful features like object detection and navigation support, they often fall short due to high costs, limited feedback detail, or complex mounting requirements.

**2.1 Existing Systems**

A number of wearable obstacle detection systems have been developed using ultrasonic sensors, computer vision, or GPS technologies. Some of the notable examples include:

**Sunu Band:** A wristband using ultrasonic sensors to detect objects and convey proximity through vibration. While non-intrusive, it provides limited context and no audio feedback.

**OrCam MyEye:** An AI-powered vision device mounted on eyeglasses, offering object recognition and audio output. Despite its advanced features, the device is prohibitively expensive and relies on the user wearing specific glasses.

**BuzzClip:** A clip-on proximity sensor that provides vibration-based feedback. It's compact but lacks verbal guidance or the ability to adapt feedback in multiple languages.

**BlindSquare (App):** A GPS-based navigation app that provides spoken directions. However, it does not detect nearby physical obstacles and is unsuitable for real-time indoor navigation.

**2.1.1 Advantages of Existing Systems**

* Compact and wearable designs.
* Offer partial assistance in both indoor and outdoor environments.
* Some solutions provide real-time feedback (via vibration or audio).
* Promote increased independence for users

##### 2.1.2 Drawbacks of Existing Systems

* Many rely on a single feedback method (mostly vibration), which may be insufficient in noisy environments or not intuitive for all users.
* Devices like OrCam are expensive and inaccessible to many users.
* Lack of customizable feedback and multilingual support.
* Often require additional accessories like specific glasses or canes.
* Battery life and comfort are often overlooked in the design phase.

**2.2 Proposed System**

The proposed system is a cap-based obstacle detection device that integrates ultrasonic sensors, an ESP32 microcontroller, and Bluetooth audio feedback. It aims to address the limitations of existing systems by offering customizable, multilingual voice messages for real-time obstacle alerts. The ESP32 provides wireless connectivity and efficient processing, while the cap design ensures discreet and hands-free usability.

Unlike existing solutions that rely on vibration or fixed feedback patterns, this system delivers clear, spoken audio alerts tailored to the user’s language preference. Additionally, users can configure the system via a companion smartphone app, adjusting distance sensitivity and selecting feedback languages or tones.

The system is designed with power efficiency in mind, utilizing the ESP32’s deep sleep modes to extend battery life, making it more practical for long-term daily use

**2.2.1 Advantages of the proposed system**

* Hands-free, comfortable design integrated into a wearable cap.
* Real-time voice feedback through Bluetooth headsets for unobtrusive alerts.
* Customizable and multilingual messages enhance clarity and accessibility.
* Low cost, using affordable components like ESP32 and ultrasonic sensors.
* Wireless configuration via mobile app for personalization.
* Battery-efficient design using sleep modes for extended usage.

**CHAPTER 3**

**SYSTEM DESIGN**

##### 3.1 Development Environment

The development environment for the wearable obstacle detection system includes both hardware and software components used for prototyping, testing, and programming. The system relies on **ESP32** as the main controller, with **ultrasonic sensors** for obstacle detection and **audio output** delivered through **wired headphones**. Prototyping is done using a **breadboard**, and final assembly is integrated into a **cap** with supporting power components like a **lithium-ion battery** and **solar panel**.

* + 1. **Hardware Requirements**
* **ESP32 Microcontroller**The core of the system; it controls sensor data processing and audio output. It features built-in Bluetooth, enabling wireless audio or app configuration.
* **Ultrasonic Sensors**  
  Measure the distance to obstacles by emitting ultrasonic waves and calculating the echo time, enabling real-time obstacle detection.
* **Breadboard**  
  Used for prototyping and testing circuit connections without soldering, allowing easy component arrangement and modifications.
* **Resistors**  
  Help regulate current flow in the circuit to protect sensitive components from damage.
* **DPF Module (Digital Power Filter)**  
  Filters electrical noise from the power supply to ensure clean and stable output, particularly important for audio quality.
* **SSD (Storage)**  
  Stores pre-recorded or system-generated voice alerts for obstacle notifications in various languages.
* **Lithium-Ion Battery**  
  Serves as a compact, rechargeable power source providing long-lasting energy for the wearable system.
* **Battery Adapter**  
  Connects the lithium-ion battery to the ESP32 board, often with built-in voltage regulation to ensure safe and stable power delivery.
* **Solar Panel**  
  Provides a renewable charging option, especially useful for extended outdoor use, improving system autonomy.
* **Headphones (3.5mm Jack)**  
  Deliver clear voice alerts to the user in real time, enabling immediate awareness of obstacles.
* **Female-to-male DPF Adapter**  
  Allows connection between standard 3.5mm headphones and the DPF audio output for reliable signal transmission.
* C**onnecting Ports & Jumper Wires**  
  Facilitate electrical connections between all modules on the breadboard and the ESP32.
* **Cap (Wearable Platform)**  
  The main housing for the system, offering a comfortable, hands-free platform to integrate all components in a user-friendly form.

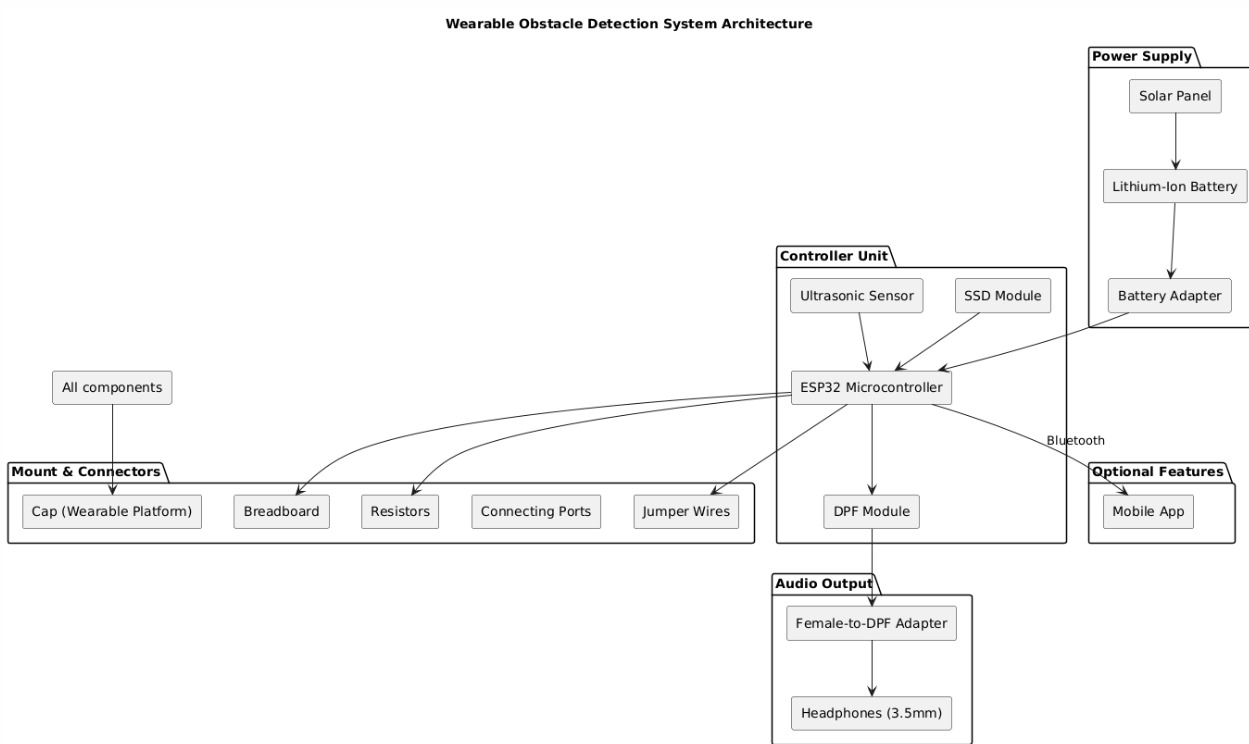
3.1.2 Software Requirements

* **Arduino IDE**  
  Used for writing and uploading firmware to the ESP32 board. The code is written in C/C++ and includes logic for sensor reading, obstacle detection, and audio feedback triggering.
* **ESP32Board Package**  
  A set of tools and definitions installed within the Arduino IDE to enable proper compiling and uploading of code specifically to ESP32-based hardware.
* **Bluetooth Audio Library**  
  Libraries that enable wireless audio streaming capabilities from the ESP32 to Bluetooth-enabled headphones or speakers (if implemented).
* **Audio File Manager / Converter**  
  Used to create, edit, or convert voice messages into compatible formats (e.g., WAV, MP3) that the ESP32 or SSD module can process and play.
* **Optional: Mobile App (Future Enhancement)**  
  Intended for future versions of the project, this app would allow users to change language settings, customize voice alerts, or adjust sensor sensitivity via Bluetooth connectivity.

**CHAPTER 4**

**PROJECT DESCRIPTION**

**4.1 SYSTEM ARCHITECTURE**



**Fig 4.1 System Architecture**

###### 4.2 METHODOLOGY

**Problem Definition**: The development of the wearable obstacle detection system followed a structured methodology to ensure functionality, usability, and accessibility for visually impaired individuals. The process involved several key phases: from defining the problem to designing, prototyping, and evaluating the system in real-world conditions.

**Literature Review**: A comprehensive literature review was conducted to investigate current assistive technologies for the visually impaired. Studies on ultrasonic-based wearables, haptic feedback systems, and commercial products like OrCam and Sunu Band were analysed. Key limitations identified included: lack of audio feedback, high costs, restricted mounting options, and minimal user customization. These insights informed the functional priorities of the proposed system—particularly the use of customizable voice alerts and hands-free design.

**Requirements Analysis:** Functional and non-functional requirements were defined based on user needs, market gaps, and technical feasibility.

* Functional Requirements: Obstacle detection in real-time, accurate distance sensing, audio output via headphones, multilingual support, and system configurability.
* Non-Functional Requirements: Portability, battery efficiency, comfort, affordability, and ease of use.

Stakeholder considerations, especially from potential users and caregivers, emphasized the need for comfort, long battery life, and discreet design.

**System Design**: The system architecture was designed with modularity and efficiency in mind.

* **Sensing Unit:** Ultrasonic sensor mounted on the cap front for clear line-of-sight detection.
* **Processing Unit:** ESP32 microcontroller for real-time data processing and Bluetooth communication.
* **Audio Output:** Wired headphones connected via DPF and SSD modules for reliable, high-quality voice feedback.
* **Power Supply:** Rechargeable lithium-ion battery supported by a solar panel for sustainable outdoor use.
* **Mounting and Integration:** Gum, double tape, and stationery materials were used to securely fix components to the cap without compromising comfort or wearability.

**Prototype Development**: The prototype was developed using a **breadboard** for initial circuit testing. All components—including ESP32, ultrasonic sensor, SSD module, DPF, and power supply—were assembled and programmed using the **Arduino IDE**. Pre-recorded multilingual voice alerts were stored and triggered based on obstacle proximity, with voice thresholds mapped to specific distances (e.g., <1m = "Obstacle ahead").

**Evaluation and Testing**: The system was tested in controlled and semi-real-world environments to evaluate its performance across key metrics:

* Accuracy of Obstacle Detection
* Clarity and Timing of Audio Feedback
* User Comfort and Usability

Field tests were conducted while walking in open areas.

**CHAPTER 5**

**RESULTS AND DISCUSSION**

This chapter presents the results obtained from testing the wearable obstacle detection system and discusses its performance across various parameters. The system was evaluated in terms of **obstacle detection accuracy**, **audio feedback clarity**, **power efficiency**, **user comfort**, and **real-time responsiveness**. The primary objective was to assess whether the proposed solution is effective, user-friendly, and viable for real-world use by visually impaired individuals.

**5.1 Testing Environment**

The prototype was tested both indoors and outdoors . Obstacles of different materials (wood, metal, fabric) and distances (0.2m to 3m) were used to evaluate sensor responsiveness. The test user wore the cap while walking toward and around these obstacles to observe system behaviour.

**5.2 Performance Metrics and Observations**

* **Obstacle Detection Range**  
  Accurate from 20 cm to 250 cm. Detected both large and small obstacles effectively.
* **Audio Feedback Delay**  
  Less than 1 second delay between obstacle detection and voice alert playback.
* **Battery Life**  
  Lasted up to 8–10 hours of continuous use. Solar panel support extended operation time, especially in outdoor use.
* **User Comfort**  
  Cap-mounted components were lightweight and evenly distributed; users reported no major discomfort even after extended use (~2 hours).
* **Wired Audio Quality**  
  Voice alerts were clear and easily audible through 3.5mm wired headphones, even in moderately noisy environments.
* **False Positives**  
  Occasionally detected non-obstacles, such as moving curtains or loose clothing, particularly at close range under 30 cm.

**5.3 Key Outcomes**

* **Real-time Detection**: The ultrasonic sensors provided consistently accurate distance measurement in real time, making the system reliable for dynamic environments.
* **Effective Audio Alerts**: The use of customizable voice alerts instead of generic beeps allowed users to better understand the nature and direction of the obstacle, which was particularly appreciated in tests.
* **Power Efficiency**: The combination of a lithium-ion battery and solar panel enabled extended usage, addressing one of the major limitations of similar commercial products.
* **Low-Cost and Practical**: All components used were affordable and locally available, bringing down the total cost significantly compared to commercial alternatives like OrCam or Sunu Band.

**5.4 Limitations**

* **Directional Feedback**: The current prototype uses a single sensor; thus, it does not indicate whether the obstacle is on the left, center, or right. Multiple sensors in future versions could enhance direction-specific alerts.
* **Noise Interference**: In very loud environments (e.g., near traffic), wired headphone audio was sometimes hard to hear. Integration with bone conduction or noise-canceling headsets may improve usability.
* **Water Resistance**: As currently built, the system lacks waterproofing, making it unsuitable for rainy weather without additional housing.

**5.5 User Feedback Summary**

Informal testing with volunteers indicated that:

* Users appreciated **clear spoken guidance** over generic signals.
* The cap form factor was considered **less intrusive** than vests or wristbands.
* Most users expressed interest in **further enhancements**, such as obstacle direction alerts or GPS integration for navigation.

**5.6 Discussion**

The results indicate that the system successfully meets its core objectives: enhancing safety, providing real-time awareness, and being accessible in terms of both cost and usability. It demonstrates that a simple yet thoughtful combination of components—ESP32, ultrasonic sensor, SSD, audio output, and a wearable form factor—can create meaningful impact in assistive technology for the visually impaired.

With iterative improvements, particularly in terms of multi-directional detection and audio enhancement, the system holds promise for real-world deployment and further development into a market-ready product.

**CHAPTER 6**

**CONCLUSION AND FUTURE WORK**

**6.1 Conclusion**

The development of the wearable obstacle detection system using an ESP32 microcontroller, ultrasonic sensors, and audio feedback marks a meaningful advancement in assistive technology for the visually impaired. By integrating the components into a lightweight, cap-based design, the system offers real-time obstacle detection and clear, customizable voice alerts—enabling users to navigate their environment more safely and independently.

The use of affordable hardware such as ultrasonic sensors and the ESP32 ensures cost-effectiveness, while features like multilingual audio feedback and solar-powered battery support increase accessibility and usability. Initial testing has shown promising results in terms of detection accuracy, user comfort, and overall functionality, making the device a strong candidate for real-world deployment with further refinement.

**6.2 Future Work**

While the current prototype achieves its primary goals, several opportunities for improvement and expansion exist:

* **Multi-Directional Sensing**: Future versions can incorporate multiple ultrasonic sensors (e.g., left, right, center) to provide directional obstacle feedback, improving situational awareness.
* **Bluetooth App Integration**: A dedicated mobile application could allow users or caregivers to adjust system settings (e.g., preferred language, sensitivity levels) via Bluetooth, making it more customizable and user-friendly.
* **Advanced Audio Feedback**: Integration with bone conduction or wireless earbuds could improve feedback clarity, especially in noisy environments, while maintaining environmental awareness.
* **Weatherproofing and Durability**: Enhancing the system's robustness with waterproof enclosures and impact-resistant materials will make it suitable for all-weather outdoor use.
* **Machine Learning Enhancements**: Future versions could incorporate basic AI to differentiate between static and moving obstacles or prioritize warnings based on obstacle type and urgency.
* **Wider User Testing**: More extensive trials with visually impaired users across diverse environments will help gather meaningful feedback and guide further iterations of the design.

By building on the current design and incorporating user-centered improvements, this project has the potential to evolve into a highly practical and impactful assistive device that improves daily navigation and autonomy for visually impaired individuals.

**APPENDIX**

**SOFTWARE INSTALLATION**

Arduino IDE

To run and mount code on the Arduino NANO, we need to first install the Arduino

IDE. After running the code successfully, mount it.

Sample code

#define ledC1 8

#define ledC2 9

#define ledC3 10

int c1, c2;

void setup() {

  Serial.begin(9600);

  pinMode(ledC1, OUTPUT);

  pinMode(ledC2, OUTPUT);

  pinMode(ledC3, OUTPUT);

}

void loop() {

  readSensor();

  if (c1 == 1 ) {

    roadCopen();

  } else {

    roadClose();

  }

}

void readSensor() {

  c1 = analogRead(A1);

  c2 = analogRead(A0);

  Serial.print(c1);

  Serial.print(&quot;\t&quot;);

  Serial.print(c2);

  Serial.println(&quot;\t&quot;);

  if (c1 &lt; 400) { c1 = 1; } else c1 = 0;

  Serial.print(c1);

  Serial.print(&quot;\t&quot;);

  Serial.print(c2);

  Serial.println(&quot;\t&quot;);

}

void roadCopen() {

  digitalWrite(ledC3, LOW);

  digitalWrite(ledC1, LOW);

  digitalWrite(ledC2, HIGH);

  delay(2000);

  digitalWrite(ledC2, LOW);

  digitalWrite(ledC1, HIGH);

  delay(2000);

  readSensor();

}

void roadClose() {

  Serial.println(&quot;ROAD STOP&quot;);

  digitalWrite(ledC3, HIGH);

  digitalWrite(ledC1, LOW);

  digitalWrite(ledC2, LOW);

  delay(15000);

  digitalWrite(ledC3, LOW);

  digitalWrite(ledC2, HIGH);

  delay(1000);

  digitalWrite(ledC2, LOW);

  delay(1000);

  digitalWrite(ledC1, HIGH);

  delay(5000);

  digitalWrite(ledC1, LOW);

  readSensor();

}

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