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Smart Railway System To Prevent Collisions

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Abstract—Railway transportation is an essential component of modern infrastructure, providing efficient and reliable transit for both passengers and freight. However, the risk of collisions due to human error, mechanical failure, or signaling issues remains a significant safety concern. The Smart Railway System for Collision Prevention aims to address these challenges by leveraging advanced technologies to enhance safety, reliability, and operational efficiency.

This uses:
- ***Ultrasonic sensor network***
- ***LiDAR based object detection***
- ***Automatic braking***

KEY WORDS- LIDAR, Automatic Breaking System, Ultra Sonic Sensor network, Motor Shield

I. INTRODUCTION

This paper presents a proposed train safety system that integrates ultrasonic sensors, LIDAR technology, and a central control unit to enhance safety. efficiency, and reliability in rail operations. The system utilizes ultrasonic sensors to provide early warnings of approaching track changing points, while LIDAR technology enables real-time obstacle detection and automatic emergency braking. A central control unit coordinates the system's operations, manages signaling systems, and monitors system performance.

While the system offers significant advantages, such as improved safety, reduced costs, and enhanced efficiency, it also faces potential challenges, including technological limitations, cost and complexity, regulatory hurdles, human factors, and cybersecurity risks. To address these challenges, careful planning, rigorous testing, and ongoing maintenance are essential.

II. COMPONENTS

1.Arduino uno

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2010. The microcontroller board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by a USB cable or a barrel connector that accepts voltages between 7 and 20 volts, such as a rectangular 9-volt battery.

Use of Arduino Uno: -
- Arduino Uno can sense and control objects in the physical world, and interact with outputs like LEDs, motors, and displays.
- Arduino Uno is a low-cost, flexible, and easy-to-use open-source board.
- It can be programmed using the Arduino programming language and the Arduino Software (IDE).

2.Arduino Nano

The Arduino Nano is an open-source breadboard-friendly microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2008. It offers the same connectivity and specs of the Arduino Uno board in a smaller form factor. The Arduino Nano is equipped with 30 male I/O headers, in a DIP-30-like configuration, which can be programmed using the Arduino Software integrated development environment (IDE), which is common to all Arduino boards and running both online and offline. The board can be powered through a type-B mini-USB cable or from a 9 V battery.

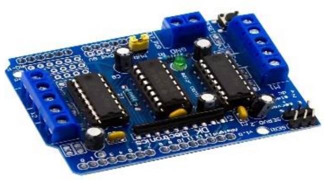
3.Ultra Sonic senors

An ultrasonic sensor is an instrument that measures the distance to an object using ultrasonic sound waves. It is a device that uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity. High-frequency sound waves reflect across boundaries to produce distinct echo patterns.

How Ultrasonic Sensors Work: -

Ultrasonic sensors work by sending out a sound wave at a frequency above the range of human hearing. The transducer of the sensor acts as a microphone to receive and send the ultrasonic sound. Our sensors, like many others, use a single transducer to send a pulse and to receive the echo. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse. This process is a key aspect of ultrasonic sensor working.

4.L293D Motor Shield



This is an extension shield that can drive 4 servos, 2 DC motors and one stepper motor. All you need to do is plug the shield into the Uno or Mega2560 board. It is powered by two sources when connected to a control board, it's powered by the output of the board; to drive a large-current motor, you can connect an external supply for the Motor Driver Shield and the control board. There's an indicator LED on the shield. When it's not in use, you can power the shield off by the switch and it won't influence the use of the control board. The working voltage is 6.5V- 12V.

5.LIDAR

LiDAR (Light Detection and Ranging) is a remote sensing technique that uses a laser to measure distances and create 3D models of the Earth's surface.

➤ A laser scanner emits short pulses of light towards the ground.

➤ The reflected light is detected by the receiver.

➤ The time it takes for the light to return is used to calculate the distance between the laser and the ground.

6.(E18-D80NK) IR Sensor

Infrared radiation (IR) Sensor sometimes referred to simply as infrared, is a region of the electromagnetic radiation spectrum where wavelengths range from about 700 nanometers (nm) to 1 millimeter (mm). Infrared waves are longer than visible light waves but shorter than radio waves.

➤ Motion detection: IR sensors are used in building services to turn on lights when motion is detected.

7.Battery

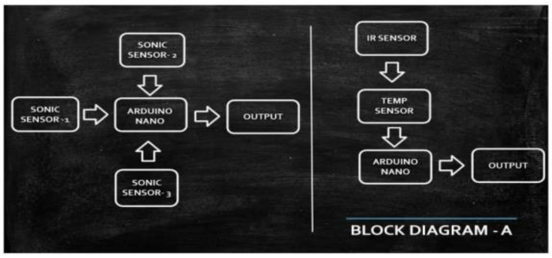
Battery, or high voltage battery, is a type of battery that can be used to power an Arduino Uno board. Some other power options for an Arduino Uno board include

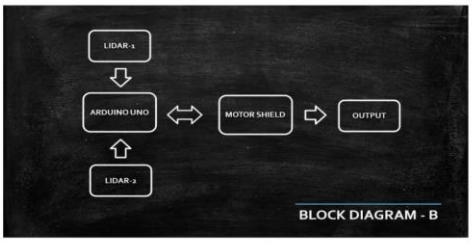
➤ Higher Energy Density: High voltage batteries can store more energy in a smaller space, making them ideal for applications where space and weight are critical factors. Efficiency: These batteries are more efficient in transferring power due to lower current requirements, which reduces energy loss.

ARDUINO CODE TO IMPLEMENT PROJECT

```
#define trigPin1 2 // Trigger pin of sensor 1
#define echoPin1 3 // Echo pin of sensor 1
#define trigPin2 4 // Trigger pin of sensor 2
#define echoPin2 5 // Echo pin of sensor 2
#define trigPin3 6 // Trigger pin of sensor 3
#define echoPin3 7 // Echo pin of sensor 3
#define buzzerPin1 8  // Buzzer pin for sensor 1
#define ledPin1 9   // LED pin for sensor 1
#define buzzerPin2 10  // Buzzer pin for sensor
#define ledPin2 11   // LED pin for sensor 2
#define buzzerPin3 12  // Buzzer pin for sensor 3
#define ledPin3 13   // LED pin for sensor 3
#define obstacleDistance 20 // Adjust this distance as
needed
void setup() {
 pinMode(trigPin1, OUTPUT);
  pinMode(echoPin1, INPUT);
  pinMode(trigPin2, OUTPUT);
  pinMode(echoPin2, INPUT);
  pinMode(trigPin3, OUTPUT);
  pinMode(echoPin3, INPUT);
 pinMode(buzzerPin1, OUTPUT);
  pinMode(ledPin1, OUTPUT);
  pinMode(buzzerPin2, OUTPUT);
  pinMode(ledPin2, OUTPUT);
  pinMode(buzzerPin3, OUTPUT);
  pinMode(ledPin3, OUTPUT);
}
void loop() {
  // Sensor 1
  long duration1, distance1;
  digitalWrite(trigPin1, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin1, LOW);
  duration1 = pulseIn(echoPin1, HIGH);
  distance1 = duration1 * 0.034 / 2;
  if (distance1 <= obstacleDistance) {
    digitalWrite(buzzerPin1, HIGH);
    digitalWrite(ledPin1, HIGH);
    } else {
    digitalWrite(buzzerPin1, LOW);
    digitalWrite(ledPin1, LOW); }
// Sensor 2
  long duration2, distance2;
  digitalWrite(trigPin2, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin2, LOW);
  duration2 = pulseIn(echoPin2, HIGH);
  distance2 = duration2 * 0.034 / 2;
 if (distance2 <= obstacleDistance) {
    digitalWrite(buzzerPin2, HIGH);
    digitalWrite(ledPin2, HIGH);
  } else {
    digitalWrite(buzzerPin2, LOW);
    digitalWrite(ledPin2, LOW);
  }  // Sensor 3
  long duration3, distance3;
  digitalWrite(trigPin3, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin3, LOW);
  duration3 = pulseIn(echoPin3, HIGH);
  distance3 = duration3 * 0.034 / 2;
 if (distance3 <= obstacleDistance) {
    digitalWrite(buzzerPin3, HIGH);
    digitalWrite(ledPin3, HIGH);
  } else {
    digitalWrite(buzzerPin3, LOW);
    digitalWrite(ledPin3, LOW);
  }
delay(100); // Adjust delay as needed
}
```

III. BLOCK DAIGRAM





IV. FUNCTIONALITY

Developing an effective smart railway system to prevent collisions involves a combination of hardware and software solutions designed to identify and mitigate potential hazards. The technology stacks used for our project are IOT and Softwares.

These are embedded with sensors, software and other technologies to collect and exchange data over the internet or other communication networks. Here's a detailed explanation of how each component operates and the overall functionality of the smart railway system

Ultrasonic Sensor Network

According to the block diagram - A phase 1 shows the ultrasonic sensor network which consists of ultrasonic sensors, signaling system and alert system.

Ultrasonic Sensors:

> High-frequency sound wave emitters and receivers.

➤ Placed at strategic distances (10 km, 5 km, and 2 km) before track changing points.

➤ Capable of detecting trains within a specific range.

Signaling System:

> Visual signals (e.g., lights and buzzers) installed at track changing points.

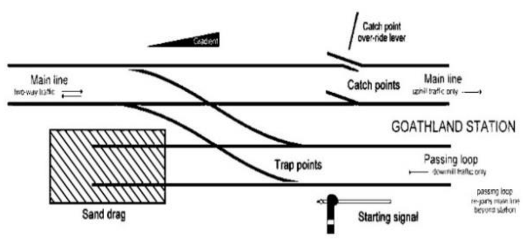
➤ Controlled by the central control unit.

Central Control Unit:

➤ Receives data from ultrasonic sensors.

➤ Processes information and activates signaling systems accordingly.

Operation



➤ Firstly, we provide an ultrasonic sensor at before 10 kms of track changing point.

➤ Secondly, we provide another ultrasonic sensor at before 5 kms of track changing point.

➤ Finally, we provide last ultrasonic sensor at before 2 kms of track changing point.

➤ Ultrasonic sensors continuously emit sound waves. When a sound wave encounters an object, it is reflected back to the sensor.

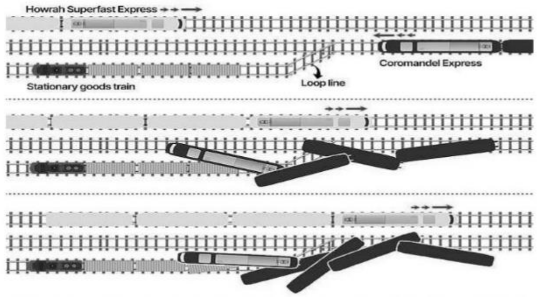
➤ And we provide signaling system at every sensor and a alerting system in the control unit.

➤ If the distance to the object is within the predefined range, the sensor sends a signal to the central control unit.

➤ When, the train is detected by the sensor at 10kms then yellow signal will be indicated on the other side & loco pilot will slow down the train.

➤ As same when detected at 5kms it shows red signal and loco pilot will stop the train.

➤ And when the train passes the sensor at 2kms then it shows green signal then loco pilot can go.



LIDAR-Based Obstacle Detection

According to the block diagram - B shows the LIDAR based obstacle detection which consists of some lidars and a motor shield for the detection and automatic braking system. LIDAR (Light Detection and Ranging) Sensors:

➤ Emit laser beams and measure the time it takes for the beams to return after reflecting off objects.

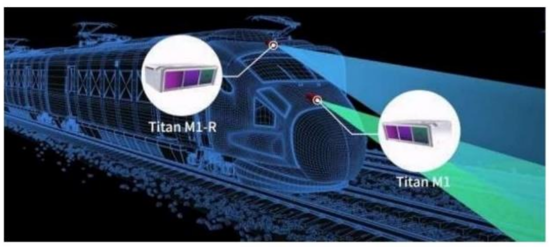
➤ Can be mounted on trains or along tracks.

Central Control Unit:

➤ Receives data from LIDAR sensors.

➤ Processes information and activates emergency braking if necessary.

Operation



➤ LIDAR sensors emit laser beams in various directions.

➤ When a laser beam encounters an object, it is reflected back to the sensor.

➤ The sensor measures the time it takes for the laser beam to travel to the object and back. This information is used to calculate the distance to the object.

➤ LIDAR systems continuously scan the area around the train and track, detecting obstacles such as debris, vehicles, trains, humans or animals.

➤ Place LIDAR sensors on trains or along tracks to cover critical areas.

➤ LIDAR can be used to scan the track and surrounding infrastructure for defects or anomalies such as track misalignment or rail wear.

➤ If an obstacle is detected within a critical distance, the system can automatically trigger emergency braking to prevent collisions.

Central Control Unit

➤ The central control unit receives data from ultrasonic sensors, LIDAR sensors, and other sources.

➤ The unit processes the data to extract relevant information, such as distances to objects, obstacle characteristics, and track conditions.

➤ The control unit continuously monitors the system's performance, generates reports, and alerts operators to any issues or anomalies.

V. ADVANTAGES

The proposed train safety system, incorporating ultrasonic sensors, LIDAR technology, and a central control unit, offers a comprehensive solution to improve safety, efficiency, and reliability in rail operations. Here are some additional, more effectively articulated advantages:

Enhanced Safety

➤ Proactive Risk Mitigation: The system proactively identifies and mitigates potential risks, reducing the likelihood of accidents.

➤ Collision Avoidance: LIDAR technology provides real-time obstacle detection, enabling the system to initiate emergency braking before a collision occurs.

Improved Efficiency

➤ Optimized Train Operations: The system provides valuable data and insights to train operators, allowing them to optimize train schedules, reduce delay , and improve overall operational efficiency.

➤ Predictive Maintenance: By identifying potential track defects early, the system can enable proactive maintenance, reducing downtime and improving overall system reliability.

Scalability and Adaptability

➤ Flexible Deployment: The system can be easily adapted to different train lines, track conditions, and operational requirements.

➤ Future-Proof: The system's modular design and ability to integrate with emerging technologies ensure its long-term viability and adaptability.

VI. FUTURE SCOPE

High-Resolution Camera

➤ Incorporating cameras with image recognition capabilities to identify train types, track conditions, and potential obstacles.

➤ Al-driven image processing can help detect anomalies and provide more detailed situational awareness.

VII. CONCLUSION

The proposed train safety system, incorporating ultrasonic sensors, LIDAR technology, and a central control unit, offers a comprehensive solution to improve safety, efficiency, and reliability in rail operations. While the system presents significant advantages, it is essential to address potential challenges, such as technological limitations, cost and complexity, regulatory hurdles, human factors, and cybersecurity risks.

By carefully considering these factors and implementing appropriate measures, railway operators can successfully deploy and operate this train safety system, reaping the benefits of enhanced safety, improved efficiency, and reduced costs. The future scope of the system is promising, with potential advancements in technology, functionality, and applications. By investing in research and development, railway operators can ensure that this system remains at the forefront of safety technology and contributes to a safer and more sustainable transportation network

VIII. ACKNOWLEDGMENT

We gratefully acknowledge the contributions of various individuals and organizations that have made the development of the Smart Railway System to Prevent Collision possible.

IX.REFERENCES

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