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Smart Metro Track Security System for Suicide Prevention

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Abstract: ***Metro rail systems are an essential mode of urban transportation, but they face serious safety challenges such as unauthorized track access and suicide attempts. This paper presents a Smart Metro Track Security System designed to enhance passenger safety using an automated embedded approach. The system integrates ultrasonic sensors for train detection and a laser–LDR mechanism for human intrusion detection. An Arduino microcontroller processes real-time data and activates safety measures such as automatic gate control, alarm generation, and power cutoff using a relay module. The system ensures immediate response to dangerous situations without human intervention. Experimental results demonstrate reliable performance under various scenarios including train arrival, departure, and intrusion detection. The proposed system is cost-effective, efficient, and suitable for real-world metro safety applications.***

Key words: Metro Safety, Arduino UNO, Ultrasonic Sensor, Intrusion Detection, Embedded System, Suicide Prevention

I. INTRODUCTION

Metro rail systems have become an essential component of modern urban transportation due to their efficiency, speed, and ability to handle large volumes of passengers. With rapid urbanization and increasing population, metro networks are expanding in major cities worldwide. However, along with these advancements, safety concerns related to metro operations have also increased significantly

One of the major issues faced in metro systems is unauthorized access to railway tracks, which often leads to accidents and suicide attempts. Such incidents not only result in loss of human life but also cause service disruptions, delays, and psychological stress among passengers and metro staff. According to various reports, a considerable number of metro-related fatalities occur due to intentional or accidental intrusion onto tracks.

Traditional safety measures such as Closed-Circuit Television (CCTV) surveillance and manual monitoring are widely used in metro stations. However, these systems have several limitations, including dependency on human operators, delayed response time, and inability to prevent incidents in real time. In many cases, by the time authorities identify a dangerous situation, it is already too late to take preventive action.

To address these challenges, there is a need for an automated and intelligent safety system capable of detecting hazardous situations and responding instantly without human intervention. Recent advancements in embedded systems, sensors, and automation technologies provide an opportunity to develop such solutions.

This paper proposes a that integrates ultrasonic sensors, a laser–LDR based intrusion detection mechanism, and an Arduino microcontroller. The system continuously monitors track conditions, detects train movement, and identifies human presence on the track. In case of intrusion, the system immediately activates safety measures such as cutting the power supply using a relay module, triggering an alarm through a buzzer, and displaying warning messages.

The proposed system aims to enhance passenger safety, reduce accidents, and provide a reliable and cost-effective solution for metro authorities. By enabling real-time monitoring and automated response, the system significantly improves the overall safety and efficiency of metro operations.

II. LITERATURE SURVEY

Recent advancements in railway and metro safety systems have focused on the use of sensors, embedded systems, and Internet of Things (IoT) technologies to improve monitoring and accident prevention.

A. Sensor-Based Detection Systems

Sensor-based approaches play a crucial role in detecting obstacles and ensuring safety in transportation systemsproposed a path planning system with obstacle avoidance using SLAM, emphasizing real-time obstacle detection and navigation.

Similarly, Patel and Shah developed an ultrasonic sensor-based obstacle detection system that provides accurate distance measurement, while Das and Banerjeehighlighted the effectiveness of ultrasonic sensors in automation and safety systems. Furthermore, Kumar and Reddy implemented a laser-based intrusion detection system using LDR sensors, which is highly effective in detecting unauthorized access to restricted areas.

B. IoT-Based Monitoring Systems

IoT-based systems enable continuous monitoring and real-time data communication. Kumar and Singh developeda smart railway track safety system using IoT and sensorsto monitor track conditions and detect obstacles. Verma andTiwari proposed an IoT-based monitoring system forrailway safety that provides real-time alerts. In addition, Kimand Park discussed IoT-based monitoring systems for smartcities, demonstrating their ability to enhance safety and operational efficiency. Kulkarni and Joshi further contributedby developing an ESP32-based wireless monitoring system,emphasizing real-time data transmission.

C. Automation and Control Systems

Automation systems reduce human intervention and im-prove operational safety. Sharma and Gupta designed anautomated railway gate control system using Arduino, which automatically controls gate operations based on train detection.Rao and Prasad demonstrated Arduino-based automationfor safety-critical systems, showing its effectiveness in real-time control. Additionally, Gupta and Mishra studiedrelay-based power control systems, which are essential foremergency power cutoff mechanisms.

D. Embedded and Intelligent Safety Systems

Embedded systems play a vital role in real-time safetyapplications. Singh and Dubey presented intelligent safetysystems using embedded technology, highlighting their abilityto automate safety operations. Mehta and Jaindesignedsmart alert systems using microcontrollers to generate alarmsduring emergencies. Brown and Williams furtheremphasized the importance of embedded systems in real-time safetyapplications. Moreover, Zhang et al. explored sensor fusiontechniques for intelligent transportation systems, improvingdetection accuracy by combining multiple sensors.

E. Research Gap

From the above studies, it is observed that most existingsystems focus on individual aspects such as obstacle detection,IoT-based monitoring, or automated gate control. While thesesystems improve safety, they lack an integrated approachthat combines train detection, human intrusion detection, andautomatic emergency response in a single system.

III. PROPOSED SYSTEM

A. System Overview

The proposed Smart Metro Track Security System is designed to enhance passenger safety by detecting train movement and unauthorized human intrusion on metro tracks in realtime. The system integrates multiple sensors and embeddedcomponents to provide automated monitoring and immediate response during hazardous situations. It reduces humanintervention and ensures faster decision-making compared totraditional systems.

B. System Architecture

The overall architecture of the system consists of three main units:

- Input Unit: Includes ultrasonic sensors and a laser-LDR pair for detecting train movement and human intrusion.
- Processing Unit: An Arduino UNO microcontroller that processes sensor data and makes decisions.
- Output Unit: Includes servo motors (gate control), relay module (power cutoff), buzzer (alert system), LEDs (visual indication), and OLED display (status monitoring).

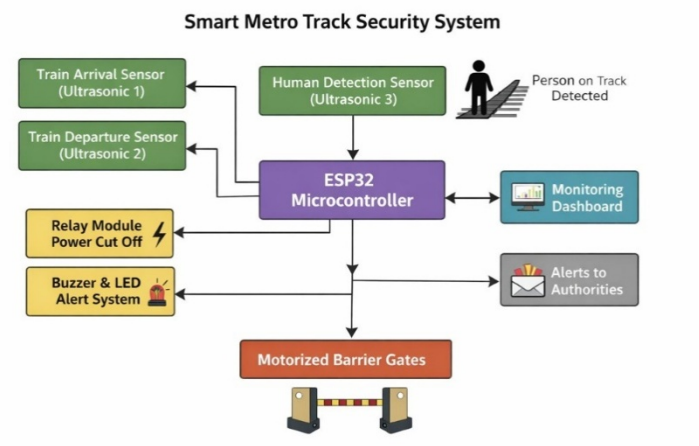

Fig.1. block diagram of metro safe vision for suicidal prevention in metro station.

C. Hardware Components

The key hardware components used in the system are:

- Arduino UNO: Acts as the central controller for processing inputs and controlling outputs.
- Ultrasonic Sensors: Used for detecting the arrival and departure of the train.
- Laser and LDR Module: Used for detecting human intrusion by sensing interruption in the light beam.
- Servo Motors: Used for automatic opening and closing of platform gates.
- Relay Module: Used to cut off power supply during emergency situations.
- Buzzer and LEDs: Provide audible and visual alerts.
- OLED Display: Displays real-time system status and warning messages.

D. System Advantages

The proposed system offers several advantages:

- Provides real-time monitoring and response
- Reduces human dependency and errors
- Prevents accidents and suicide attempts
- Cost-effective and easy to implement
- Suitable for integration into existing metro systems

IV. METHODOLOGY

The methodology of the proposed system describes the step-by-step operational procedure used to detect train movementand human intrusion, and to initiate appropriate safety actionsin real time.

A. Working Principle

The system operates continuously by monitoring sensor inputs and executing control actions based on predefined conditions. The complete working process is described as follows:

1) Initialization: All sensors, including ultrasonic sensors and the laser-LDR module, are initialized along with output devices such as servo motors, buzzer, relay, LEDs, and OLED display.

2) Train Arrival Detection: The first ultrasonic sensor continuously measures the distance on the track. When a train approaches within a predefined threshold distance, the sensor sends a signal to the Arduino microcontroller. The controller processes this signal and activates the servo motor to open the platform gate.

3) Train Departure Detection: The second ultrasonic sensor detects the departure of the train. Once the train moves away beyond a certain distance, the Arduino automatically closes the gate using the servo motor.

4) Intrusion Detection: A laser beam is directed continuously towards the LDR sensor. Under normal conditions, the LDR receives constant light intensity. When a person enters the track, the laser beam is interrupted, causing a change in resistance of the LDR. This change is detected by the Arduino.

5) Emergency Response Mechanism: Upon detecting intrusion, the system immediately performs the following actions:

- Activates the buzzer to generate an alarm
- Turns on warning LEDs for visual indication
- Displays alert messages on the OLED screen
- Cuts off the power supply using the relay moduleto prevent train movement

6) System Reset: After the hazard is cleared, the systemresets automatically and resumes normal monitoringoperation.

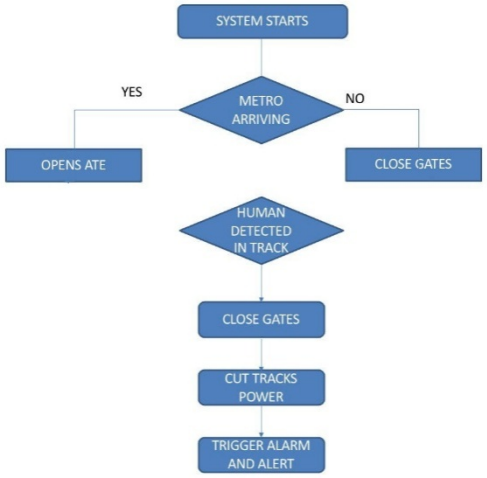

Fig.2. flow chart for metro safe vision.

E. Circuit Design

The circuit design integrates all sensors and output components with the Arduino UNO microcontroller to ensureefficient real-time operation. Ultrasonic sensors are connectedto digital input pins for distance measurement and traindetection. The laser–LDR module is interfaced through ananalog input using a voltage divider configuration for accurateintrusion detection. Servo motors are connected to PWM pinsfor automatic gate control, while the relay module is interfacedthrough a digital output to control the power supply duringemergency conditions. Additionally, the buzzer and LEDs areconnected to digital pins to provide audible and visual alerts,and the OLED display is interfaced via I2C communicationto display system status and warning messages.

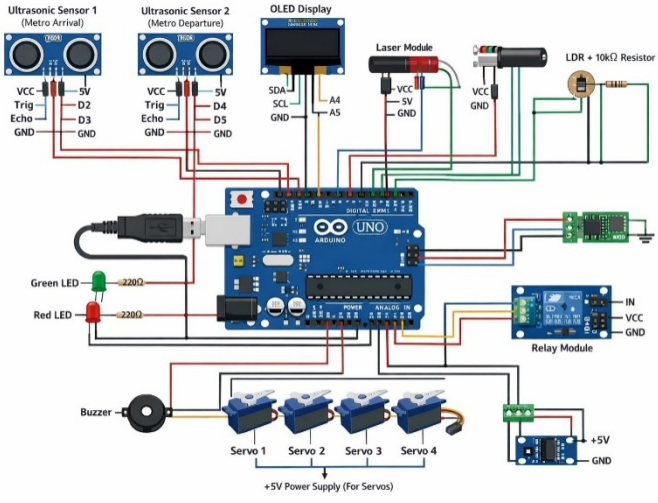

Fig.3. circuit diagram

V. RESULTS AND DISCUSSION

The proposed Smart Metro Track Security System was implemented and tested under different operating conditions to evaluate its performance. The system was analysed based on train detection, gate control, and intrusion detection capabilities. The results demonstrate reliable and accurate operation in real-time scenarios.

A. Hardware Implementation

The complete hardware prototype of the system is shown inFig. 4. The setup includes Arduino UNO, ultrasonic sensors,laser-LDR module, relay, servo motors, buzzer, LEDs, andOLED display.

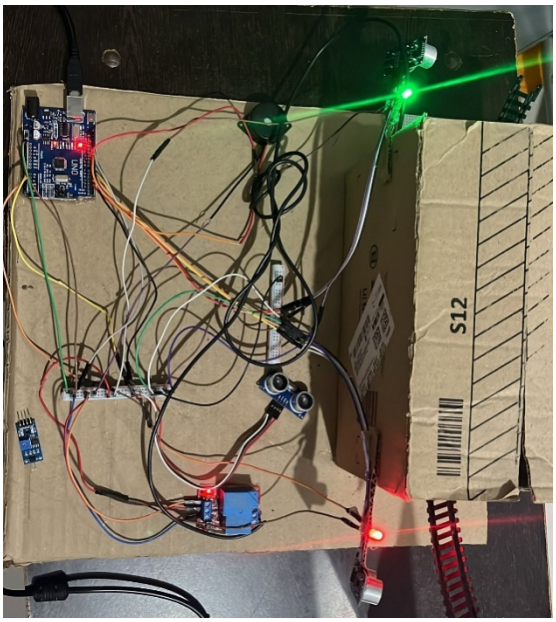

Fig.4. Hardware implementation of the project

B. Train Arrival Detection

During testing, the first ultrasonic sensor successfully detected the approaching train within the predefined thresholdFig. 4. Hardware Implementation of Smart Metro Track Security Systemdistance. Upon detection, the Arduino triggered the servomotor to open the platform gate automatically. The responsetime was observed to be fast and consistent.

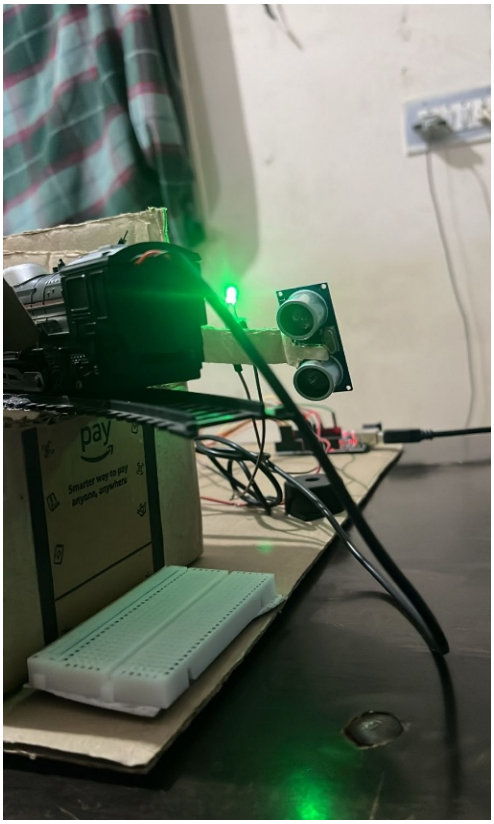

Fig.5. metro arrival detected in sensor.

C. Train Departure Detection

The second ultrasonic sensor detected the departure of thetrain. Once the train moved away from the sensing range, thesystem automatically closed the gate. This ensured safe andcontrolled operation without manual intervention.

Fig.6. metro departure detect in sensor.

D. Intrusion Detection and Safety Response

The laser-LDR module effectively detected human intrusion on the track. When the laser beam was interrupted, the Arduino immediately activated the emergency response mechanism. The buzzer generated an alarm, LEDs provided visual alerts, and the relay module cut off the power supply. The system responded instantly, preventing potential accidents.

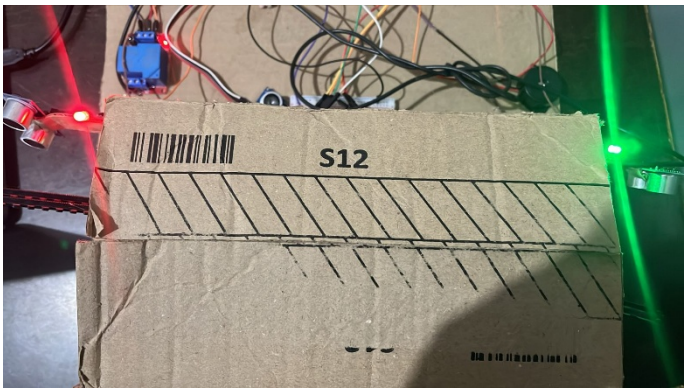

Fig.7. LED alert system when intrusion detection.

E. Performance Analysis

The experimental results indicate that the system performs efficiently under real-time conditions. The ultrasonic sensors provided accurate distance measurement for train detection, while the laser-LDR setup ensured reliable intrusion detection. The response time of the system was minimal, and all safety mechanisms were activated without delay.The system is cost-effective, easy to implement, and suitable for practical metro safety applications. However, environmental factors such as lighting conditions and sensor alignment may affect performance, which can be improved in future work.

VI. ADVANTAGES

- Prevents accidents and suicide attempts
- Fully automated system
- Low cost and efficient
- Real-time response

VII. LIMITATIONS

- Sensor accuracy affected by environment
- Limited detection range

VIII. FUTURE SCOPE

Future improvements include:

- AI-based monitoring
- IoT integration
- Mobile alert systems
- Cloud data storage

IX. CONCLUSION

The proposed Smart Metro Track Security System provides an effective and reliable solution to enhance safety in metro rail environments. By integrating ultrasonic sensors for train detection and a laser–LDR mechanism for human intrusion detection, the system is capable of continuously monitoring track conditions in real time. The use of an Arduino-based embedded system enables automated decision-making and rapid response without the need for human intervention.Upon detecting a hazardous situation, the system promptly activates safety measures such as gate control, alarm generation, visual alerts, and power cutoff using a relay module. This immediate response helps in preventing accidents and reducing the risk of suicide attempts on metro tracks. The experimental results demonstrate that the system performs efficiently under different scenarios, including train arrival, departure, and intrusion detection.

Overall, the system is cost-effective, easy to implement, and suitable for enhancing passenger safety in metro stations. Although the current design is a prototype, it has significant potential for real-world applications with further improvements such as integration of IoT technologies, advanced sensors, and intelligent monitoring systems. The proposed solution contributes toward building safer and smarter metro transportation systems.

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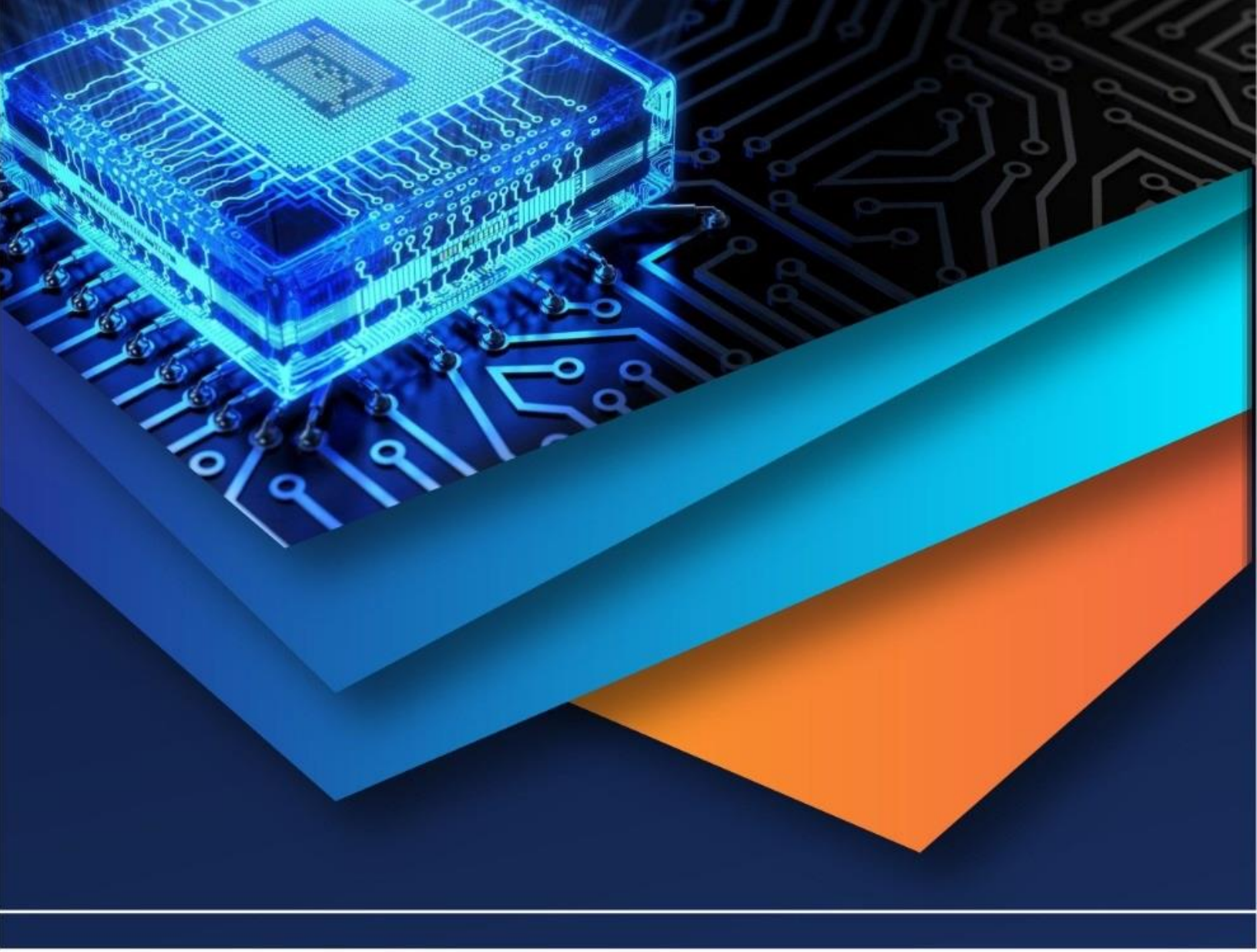

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