IoT Based Public Transportation Accident Prevention with Driver Alcohol Detection and Smoke System

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ABSTRACT

In Nigeria, 1,834 deaths were recorded from 3,345 road accidents between January and March 2022, according to the National Bureau of Statistics (NBS), underscoring the critical need for improved road safety measures. This study proposes an IoT-based system designed to prevent accidents in public transportation by addressing two major risk factors: alcohol-impaired driving and smoking while driving. The system utilizes MQ3 and MQ2 sensors for alcohol and smoke detection, respectively, which are installed within the vehicle interior. These sensors are connected to a central control unit that processes data in real-time. Upon detection of alcohol or smoke, the system triggers visual and auditory alerts, deactivates the vehicle's engine, and sends notifications to the relevant transportation authority. The architecture of the system ensures seamless data communication, allowing for remote monitoring and control. The findings demonstrate the potential of IoT-driven solutions in reducing road accidents and underscore the importance of integrating sensor technology, real-time data processing, and wireless communication for next-generation accident prevention.

Keywords: Internet of Things (IoT), accident prevention, driver alcohol detection, smoke sensing, road safety, real-time monitoring, wireless communication, Public transportation, safety.

INTRODUCTION

Experiencing the loss of loved ones due to a preventable motor accident can be an incredibly painful and heart-wrenching ordeal, especially when the accident could have been averted through simple common-sense measures. Smoking and alcohol consumption are prevalent practices across many cultures, often tied to traditions, celebrations, and personal occasions. However, even a modest amount of alcohol can significantly impair human behaviour, leading to reduced perceptual abilities and slower reaction times. Consequently, a person driving under the influence of alcohol faces a significantly higher risk of being involved in a car accident. Law enforcement agencies in Nigeria are diligently working to regulate and reduce the prevalence of alcohol consumption among the country's public drivers. This effort is driven by the recognition of the critical role that sobriety plays in ensuring road safety and preventing accidents. These agencies are actively engaged in various initiatives and enforcement measures aimed at discouraging alcohol consumption and enforcing strict adherence to established legal limits for alcohol consumption among drivers. These efforts are pivotal in safeguarding both the drivers themselves and the general public who share the roadways. The Internet of Things (IoT) plays a crucial role in addressing alcohol-related issues among public drivers in Nigeria. IoT technology enables real-time monitoring of drivers' alcohol levels through non-intrusive sensors integrated into vehicles. It provides immediate alerts to authorities when alcohol levels exceed legal limits, allowing for swift action. IoT can immobilize vehicles with dangerously high alcohol levels, reducing accident risks (Altaf et al., 2017). IoT-generated data helps identify trends and risk factors associated with drunk driving, informing targeted interventions and awareness campaigns. Additionally, it can prevent vehicle start-up if alcohol levels are excessive, acting as a deterrent (Lakshmi, 2018).

Figure 1: IoT Application in Transportation System (Zhao et al., 2014)

IoT delivers real-time educational content to drivers, emphasizing responsible behaviour and reinforces evidence-based policies. It streamlines law enforcement efforts, allocating resources efficiently, and enhances transparency, building public trust in safety measures (Vijay et al., 2019).

This study proposes an IoT-based system specifically designed to address the dual threats of alcohol-impaired driving and smoking in public transportation vehicles. The system integrates MQ3 and MQ2 sensors for detecting alcohol and smoke, respectively, within the vehicle's interior. These sensors are connected to a central control unit responsible for processing the data in real-time. Upon detecting hazardous conditions, the system activates visual and auditory alerts, disables the vehicle's engine, and transmits notifications to designated transportation park authorities.

The objective of this research is to explore the potential of IoT-driven safety systems in reducing the incidence of accidents caused by impaired driving and smoking. By leveraging sensor technology, real-time data processing, and wireless communication, this system aims to establish a robust framework for next-generation accident prevention mechanisms in public transportation. The findings of this study are expected to contribute significantly to the ongoing efforts to enhance road safety in Nigeria and other similar contexts.

Related Works

The integration of IoT technologies in road safety has been extensively researched, with studies such as Bhatti et al. (2021) exploring the use of IoT-enabled devices for real-time traffic monitoring and accident detection. Their research demonstrated the potential of IoT to facilitate quicker response times and improve overall traffic management, highlighting its broader applicability in enhancing road safety. Similarly, the development of alcohol detection systems in vehicles has been a focal point of numerous studies. For instance, Kommey et al. (2022) designed a vehicle ignition control system that utilizes alcohol sensors to prevent drunk driving by automatically disabling the vehicle’s engine when alcohol levels exceed a certain threshold. This study laid the groundwork for integrating alcohol sensors with vehicle control systems, which is highly relevant to the alcohol detection component of the proposed research.

Smoke detection within vehicles, particularly in public transportation, has also been explored. Kshirsagar et al. (2020) developed a smoke detection system aimed at reducing fire hazards in buses, using sensors connected to an alarm and engine cut-off mechanism. Their findings highlighted the importance of early smoke detection in accident prevention, paralleling the smoke detection approach of the current study. Moreover, real-time monitoring and alert mechanisms have been shown to improve response times and reduce accident severity. Tao and Lu (2020) introduced an IoT-based vehicle tracking system that provides real-time updates on vehicle conditions and sends alerts in case of anomalies. Their research emphasizes the significance of real-time data processing and immediate intervention, which are central aspects of the proposed IoT system.

Wireless communication also plays a crucial role in enhancing the safety and efficiency of transportation systems. Celesti et al. (2017) discussed the use of wireless technologies, such as GSM and GPS, to transmit critical data from vehicles to central monitoring stations. Their work demonstrated how wireless communication can be leveraged to enhance the monitoring and control of public transportation systems, aligning with the remote notification feature of the proposed system. Additionally, the integration of multiple sensors for comprehensive vehicle safety has been explored in several studies. Lee et al. (2017) developed a multi-sensor system for accident prevention, combining speed, proximity, and alcohol sensors to monitor driver behavior and vehicle conditions. Their findings support the effectiveness of using multiple sensors to enhance safety, which is mirrored in the multi-sensor approach of the proposed IoT system.

Furthermore, the focus on improving safety within public transportation has been emphasized in studies like that of Milanés et al. (2011), who examined the use of surveillance cameras and automated braking systems in buses to reduce accidents. Their research underscored the need for tailored safety solutions in public transportation, which is the central focus of the current study on IoT-based accident prevention. Finally, the development of smart vehicles equipped with IoT capabilities has gained significant attention. Garcia et al. (2022) presented a smart vehicle system that integrates IoT devices for collision avoidance and driver assistance, using real-time data analytics and sensor integration. Their work provides valuable insights into the application of IoT in creating safer and more efficient transportation systems, directly informing the design and objectives of the proposed study.

This body of related work provides a strong foundation for understanding the potential and application of IoT technologies in public transportation safety, particularly in the context of preventing accidents caused by impaired driving and smoking. The proposed study builds upon these findings to contribute to the ongoing efforts to enhance road safety through advanced technological solutions.

System Design

Figure 1 illustrates the block diagram of the envisioned system. This design prioritizes affordability and simplicity while maintaining adequate accuracy to deliver meaningful Smoke and Alcohol Concentration (SAC) measurements. The system hardware comprises seven key components, including the ATMEGA, power supply unit, alcohol and smoke sensor, Gsm module, light emitting diode, buzzer, and relay module.

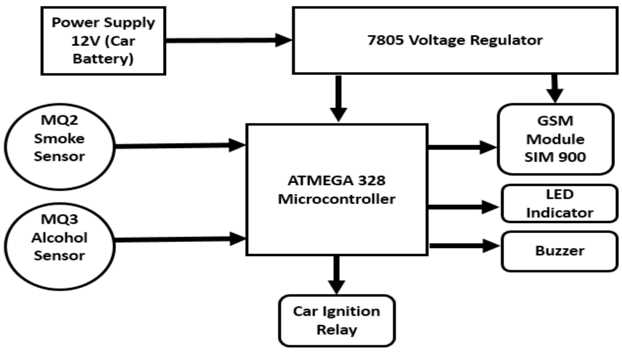

Figure 1: Block Diagram

The Hardware Architecture

The system's hardware design consists of sensors, a microcontroller, a relay, light-emitting diodes (LEDs), a GSM module, a buzzer, and other electronic components. The MQ-3 alcohol sensor detects alcohol concentration from the driver's breath, while the MQ-2 smoke sensor monitors smoke levels from the driver's seat. Both sensors are positioned near the steering wheel for accurate detection. When the alcohol or smoke concentration exceeds a specified threshold, the sensors send signals to the microcontroller. This triggers the relay and LEDs to alert the driver, disables the engine ignition system, activates the buzzer, and prompts the GSM module to send a message to law enforcement or motor park authorities.

ATMEGA 328 Microcontroller

This is the heart of the system, responsible for data processing and control logic. As shown in Figure 2, the

ATMEGA328 microcontroller is an 8-bit microcontroller belonging to the Atmel AVR family, and it's renowned for its versatility (Shreyas C. et al., 2021). It's widely used in a variety of applications, ranging from hobbyist projects to industrial automation and robotics. This microcontroller is based on the Harvard architecture, featuring separate program memory (Flash) and data memory (SRAM). It operates at a clock speed of 8 MHz and executes most instructions in a single clock cycle. In terms of memory, the ATMEGA328 offers 32KB of Flash program memory, 2KB of SRAM data memory, and 1KB of EEPROM for non-volatile data storage. Its rich set of peripherals includes digital I/O pins, analog-to-digital converters (ADCs), timers/counters, UART communication, and PWM channels, making it highly adaptable for interfacing with various sensors, actuators, and communication devices. With 23 general-purpose digital I/O pins (including PWM-capable pins), the ATMEGA328 can be configured as inputs or outputs, providing extensive flexibility for connecting external devices. Its 10-bit ADC is equipped with multiple input channels for converting analog signals from sensors into digital values for processing. Additionally, it supports UART communication, essential for interfacing with various external devices (Rohan et al.2019).

Figure 2: ATMEGA 328 Microcontroller Chip

The microcontroller features three timers/counters, enabling tasks such as generating precise time delays, PWM signal generation, and event counting. Its programming can be done through various development environments, including the user-friendly Arduino IDE. Furthermore, the ATMEGA328 offers power-saving modes and low power consumption, making it suitable for applications requiring battery power or energy efficiency.

The ATmega328 microcontroller acts as the central processing unit in the project, receiving and interpreting signals from the MQ-3 alcohol and MQ-2 smoke sensors. It processes these signals to determine if alcohol or smoke concentrations exceed predefined thresholds. Upon detection, the microcontroller controls the relay, LEDs, buzzer, and GSM module to initiate appropriate alerts and notifications.

MQ 3 Alcohol Sensor

The MQ-3 sensor, as depicted in Figure 3, is classified as a conductometric Metal Oxide Semiconductor (MOS) gas sensor. It exhibits rapid response times and remarkable sensitivity specifically to alcohol. This sensitivity is accompanied by a notably reduced responsiveness to other gases, such as benzine, methane, hexane, propane, and carbon monoxide. The sensor's sensitive material comprises a thin film of SnO_2, which stands for stannic oxide or tin dioxide (Syue et al., 2022). In its pristine state, this material possesses low electrical conductivity when exposed to clean air. The MQ-3 sensor falls under the category of n-type MOS sensors. When it comes into contact with alcohol, its conductivity experiences a proportional increase in tandem with the alcohol concentration. This sensitivity allows it to detect alcohol concentrations ranging from 0.05 mg/l to 10 mg/l (Syue et al., 2022).

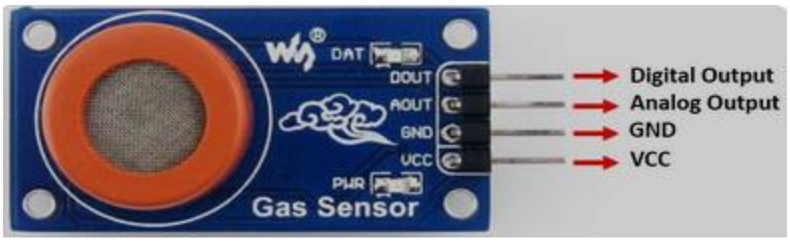

Figure 3: MQ 3 Sensor Pin Configuration

Furthermore, the MQ-3 sensor demonstrates operational versatility, functioning effectively within a temperature range spanning from 10°C to 70°C. It achieves its functionality through a heating element, where the heater coil draws a current of 150 mA. The MQ-3 sensor detects alcohol concentration in the driver's breath by measuring the level of ethanol vapor. It provides real-time data to the microcontroller, which uses this information to assess whether alcohol levels exceed the safety threshold. If alcohol concentration is too high, the sensor triggers the system's alerts and deactivates the engine as part of the overall safety protocol.

MQ 2 Smoke Sensor

The MQ-2 gas sensor as shown in Figure 4, particularly in terms of smoke sensing, is a valuable component known for its effectiveness in detecting smoke particles and combustion byproducts. Its working principle relies on a chemiresistive mechanism, where a tin dioxide (SnO_2) thin film serves as a gas-sensitive resistor. When exposed to smoke particles and combustion gases, the electrical conductivity of the SnO2 film changes (Rohan et al., 2022). This sensitivity to smoke makes the MQ-2 sensor a crucial component in fire detection systems and smoke alarms. It is capable of promptly detecting the presence of smoke when the driver is smoking.

Figure 4: MQ 2 Sensor

Due to its quick response time and ability to sense smoke in various environments, the MQ-2 sensor is effective for this purpose. The sensor's versatility extends beyond smoke detection, as it can also sense a range of other gases, such as LPG, methane, carbon monoxide, and more. This adaptability makes it suitable for a wide array of applications where gas detection and safety are paramount concerns. The MQ-2 sensor detects the presence of smoke and high concentrations of gases such as carbon monoxide and methane. Positioned near the driver's seat, it monitors for smoke levels that might indicate hazardous conditions. When smoke concentration surpasses a set threshold, the sensor sends a signal to the microcontroller, triggering alerts and engine deactivation to ensure safety.

SIM 900 GSM Module

The SIM900 GSM module as shown in Figure 5 operates based on a fundamental working principle that facilitates mobile communication. This module is often integrated into devices and systems for sending and receiving data, messages, and calls over the Global System for Mobile Communications (GSM) network (Gabriel, 2018). At its core, the SIM900 module works by establishing a connection with a cellular network provider. It does this by communicating with a Subscriber Identity Module (SIM) card, which contains crucial user and network information. Once connected to the GSM network, the module can transmit and receive data.

Figure 5: SIM900 Module

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The SIM900 module employs the AT command set, a standard set of commands used for controlling and configuring modem-like devices. These commands enable users to perform various tasks, including sending text messages, making phone calls, and connecting to the internet. To send data or text messages, users send specific AT commands to the module, which then encodes the data and transmits it over the GSM network to a designated recipient. Conversely, when receiving data or messages, the module decodes the information and makes it available for further processing by the host system (Flescher et al., 2012). The module relies on the GSM network's infrastructure for seamless communication, making it a valuable component in applications like remote monitoring, telematics, and IoT devices. Its simplicity and compatibility with standard AT commands contribute to its widespread use in numerous projects and applications (Mandalkar et al., 2015). The SIM900 GSM module enables wireless communication by sending real-time alerts and notifications to law enforcement or motor park authorities. It transmits messages triggered by the microcontroller when hazardous conditions, such as high alcohol or smoke levels, are detected. This ensures prompt response and intervention in case of safety breaches.

Relay Module

A relay is an electromechanical switch employed for the management of devices with higher voltage and current requirements. This apparatus offers electrical isolation from the control circuit, safeguarding the Microcontroller board from potential electrical hazards. Enclosed within the relay are two essential components: mechanical switch contacts and a low-voltage coil.

Figure 6: Relay Module

When an electric current begins to traverse the coil, it engenders an electromagnetic field, thereby initiating an electrical connection or switching action. Conversely, upon cessation of the current flow through the coil, the connection is disengaged or deactivated (Arun & Kenneth, 2012). This mechanism allows the relay to effectively control the flow of higher voltage and current, ensuring the safe operation of connected devices while shielding the microcontroller from any adverse effects. The relay module acts as an intermediary switch controlled by the microcontroller, allowing the system to manage high-power components like the engine ignition system. When the microcontroller detects hazardous conditions, the relay module deactivates the engine and engages other alerts. This control helps prevent the vehicle from operating under unsafe conditions. This is the logical model for the relay control: logical model for the relay operation:

Define the Inputs:

1. A = Alcohol concentration detected by the MQ-3 sensor
2. S = Smoke concentration detected by the MQ-2 sensor
3. Ta = Threshold alcohol concentration
4. Ts = Threshold smoke concentration

Relay Control Logic:

5. If *A>Ta* or *S>Ts* , then the relay should be activated to disable the engine and trigger alerts.

Relay Activation Equation:

$$R=IF(A>Ta\ OR\ S>Ts)\ THEN\ 1\ ELSE\ 0$$

where R represents the relay state:

6. R=1 indicates that the relay is activated (engine is disabled and alerts are triggered).
7. R=0 indicates that the relay is deactivated (engine operates normally).

In this model, the relay is controlled based on whether any of the sensor readings exceed their respective thresholds, ensuring that the vehicle is disabled in unsafe conditions.

System Circuit Design

As shown in figure 7, the microcontroller's core responsibility in this designed system is to process incoming data from various sensors, including the MQ3 alcohol sensor and MQ2 sensor. It achieves this by executing a series of programmed instructions, or a firmware, which directs how data should be collected, analysed, and acted upon.

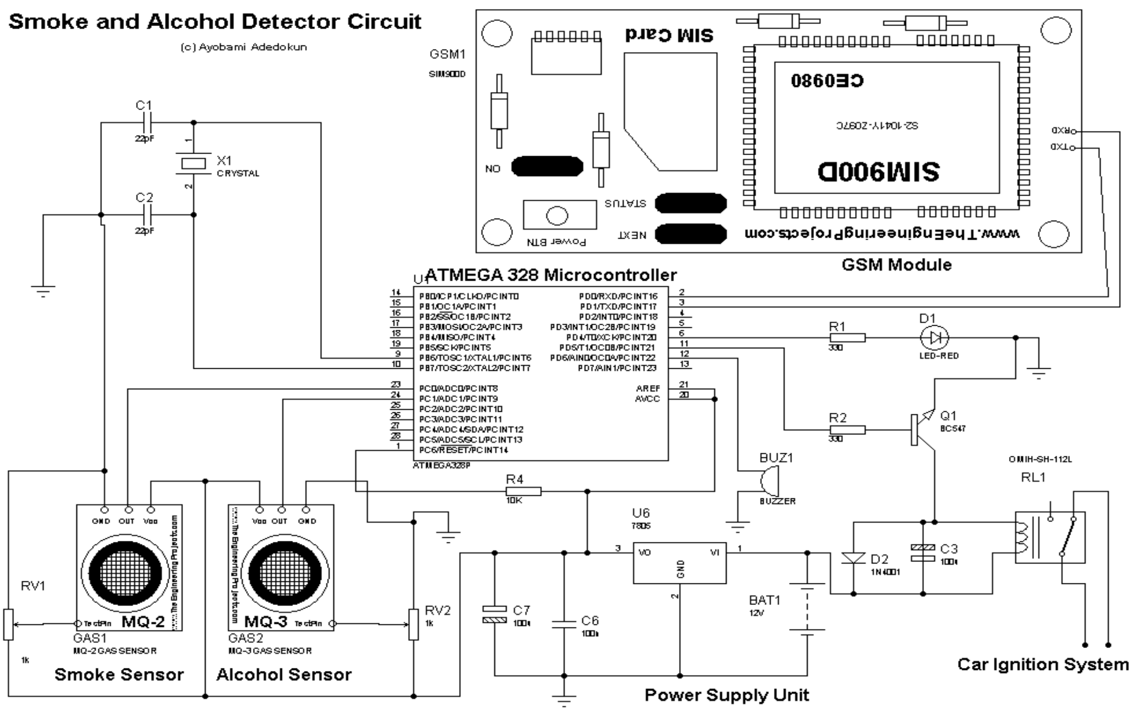

Figure 7: The System Circuit Diagram

The ATmega328 microcontroller plays a crucial role in the system by interfacing with the alcohol and smoke sensors to monitor and analyze changes in electrical resistance. These sensors, when exposed to alcohol vapors or smoke, alter their resistance levels in response to the concentration of these substances. The ATmega328 reads these resistance changes through its analog-to-digital converters, converting them into meaningful data about the presence and concentration of alcohol and smoke. Upon receiving data from the sensors, the microcontroller processes this information to determine whether the detected levels exceed predefined safety thresholds. If the levels of alcohol or smoke are found to be above these thresholds, the ATmega328 initiates a series of pre-programmed responses to ensure safety. Specifically, it triggers visual and auditory alerts to warn the driver of hazardous conditions, activates an LED to provide a clear visual indication, and deactivates the vehicle's ignition

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system to prevent operation under unsafe conditions. Additionally, the microcontroller interfaces with the GSM module to send real-time alert messages to law enforcement or transportation authorities, enabling timely intervention. This operational sequence illustrates the ATmega328's pivotal role in maintaining road safety. By continuously monitoring sensor data and executing corrective actions based on real-time information, the microcontroller helps mitigate risks associated with alcohol impairment and smoking while driving, ultimately contributing to a safer driving environment.

Gas Sensor Sensitivity

Gas sensor sensitivity refers to the sensor's ability to detect and respond to changes in gas concentration. A highly sensitive sensor exhibits a more significant change in electrical properties, such as resistance, in response to even minor variations in gas concentration, making it capable of detecting low levels of gases (Syue et al., 2022).

$$C = \left(\frac{Rs}{Ro}\right) \wedge \left(\frac{1}{m}\right) \times A \qquad (1)$$

where C is the gas concentration in ppm, Rs is the sensor resistance in the presence of the target gas, Ro is the sensor resistance in clean air, m is the sensor sensitivity exponent (varies for different gases), A is a constant related to the specific gas and this paper considered alcohol and smoke (Mitsubayashi et al., 2004).

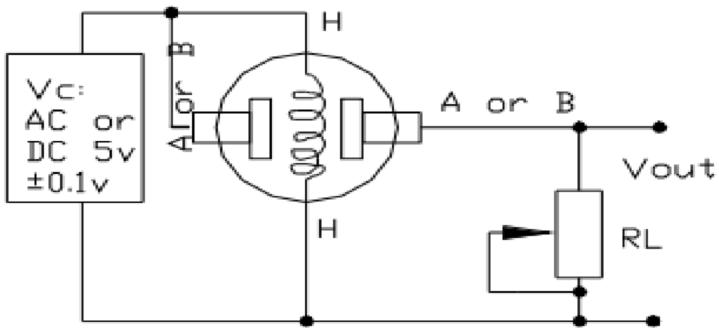

Figure 8: MQ 3 and MQ 2 Sensor Sensitivity Circuit (Madvar et al., 2020)

The sensitivity of a gas sensor, such as the MQ-2 or MQ-3, can be modeled using an equation that relates the sensor's output to the concentration of the detected gas. For many gas sensors, sensitivity can be approximated by the following empirical equation:

$$Gc = K \times \frac{Vout}{Vref} \qquad (2)$$

In the equation for gas sensor sensitivity, Gc represents the gas concentration in parts per million (ppm). The term $Vout$ denotes the output voltage measured from the gas sensor, which varies based on the concentration of the detected gas. $Vref$ is the reference voltage, typically set to the supply voltage or a known calibration value used for comparison. The sensitivity constant, K is a coefficient that depends on the specific type of sensor and the gas being detected, and it is used to convert the sensor's output into a concentration measurement.

RESULT AND DISCUSSION

Table 1: Sensor Resistance Variation (Madvar et al., 2023)

S/N	Rs (Sensor Resistance in Ohm)	Ro (Clean Air Resistance in Ohm)	Gas Sensitivity (m)	Constant (A)	C (Gas Concentration in ppm)
1	1000	2000	2.5	100	79.37

2	800	2000	3.0	80	125.99
3	1500	1800	2.2	120	40.79
4	1200	2100	2.8	90	98.16
5	900	1900	2.6	110	61.51

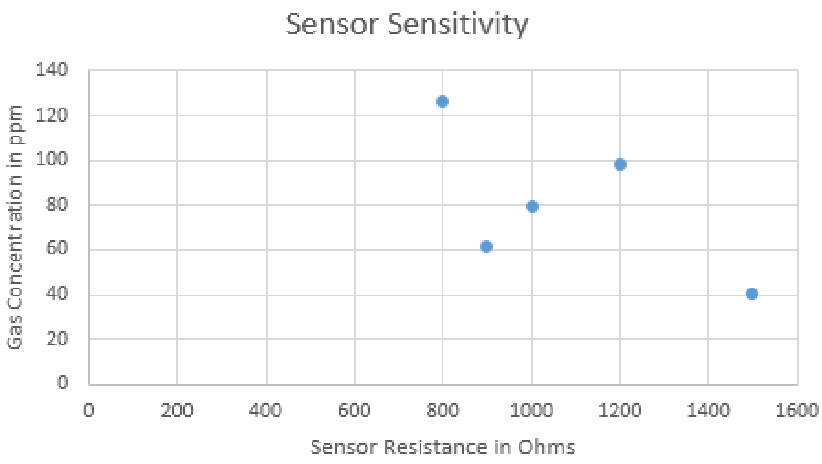

Figure 9: Sensor Sensitivity

It reveals an inverse relationship, where an increase in gas concentration generally leads to a decrease in sensor resistance, showcasing the sensor's ability to detect changes in the environment. The slope of the graph provides essential information about sensor sensitivity. A steeper slope indicates higher sensitivity, signifying that the sensor can discern even minor shifts in gas concentration. Understanding the slope aids in fine-tuning sensor sensitivity for precise gas detection. Moreover, the graph helps define the sensor's operational range, showing the minimum and maximum concentrations it can reliably measure. Crucially, this graph is instrumental in sensor calibration, allowing for the establishment of mathematical relationships between Rs and gas concentration, thus ensuring accurate and dependable gas detection in real-world applications. Overall, it serves as a fundamental analytical tool for optimizing gas sensor performance and achieving tailored results in various gas monitoring scenarios.

Also, other test was carried on to evaluates the performance of the IoT-based public transportation accident prevention system. The testing phase includes the assessment of sensor accuracy, system response times, and overall effectiveness in detecting hazardous conditions as shown in table 2.

S/N	Alcohol Concentration (ppm)	Smoke Concentration (ppm)	Sensor Output (V)	Relay Status	LED Status	Buzzer Status	GSM Notification status
1	0	0	0.10	OFF	OFF	OFF	No
2	50	0	0.30	OFF	ON	OFF	No
3	0	100	0.45	OFF	OFF	ON	No
4	70	120	0.60	ON	ON	ON	Yes
5	20	150	0.25	OFF	OFF	OFF	No
6	80	60	0.55	ON	ON	ON	Yes

The table presents test results for the system's response to varying levels of alcohol and smoke concentrations. It shows how different concentrations of these substances affect the sensor outputs and trigger system components such as the relay, LED, buzzer, and GSM module. For instance, when both alcohol and smoke concentrations exceed their respective thresholds, the system activates all alerts and sends a GSM notification, demonstrating the system's effectiveness in responding to hazardous conditions. The figure 10 shows the relationship between gas concentration and distance from the sensor. Two lines are plotted: one for alcohol concentration and one for smoke concentration, each showing how the levels of these substances vary with increasing distance. As the distance from the sensor increases, both alcohol and smoke concentrations show a rising trend, indicating that the sensor detects higher levels of gas further away. The alcohol concentration increases more steeply compared to smoke concentration, reflecting different diffusion characteristics of the gases. This visualization helps in understanding how gas concentrations are distributed with distance, which is crucial for optimizing sensor placement and calibration.

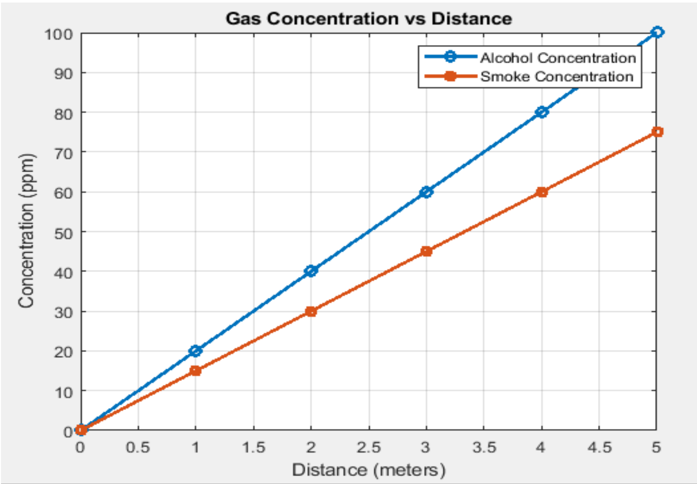

Figure 10: Relationship between concentration and distance

CONCLUSIONS

In conclusion, the IoT-based public transportation accident prevention system effectively integrates alcohol and smoke sensors with a microcontroller to enhance road safety. The system successfully detects hazardous conditions, such as high levels of alcohol and smoke, and activates appropriate alerts and preventive measures, including engine deactivation and GSM notifications. Testing confirms that the system responds accurately to varying concentrations of these substances, demonstrating its reliability in real-world scenarios. This approach highlights the potential of IoT technologies in mitigating risks associated with impaired driving and smoking. Overall, the system presents a robust solution for improving safety in public transportation. This project holds significant potential for reducing accidents caused by impaired driving and smoke-related incidents, contributing to overall road safety and the well-being of all road users. Here are suggestion for improvement on the project:

i. An upgrade to more precise sensors or improve calibration methods for better detection reliability.

ii. Using machine learning to analyze data and improve the system's adaptability to varying conditions.

iii. Add features like video surveillance or fatigue monitoring to provide a more comprehensive safety solution.

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