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CO Vigilance: Empowering Vehicle Safety with Health Alert Technology

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Abstract: The CO Vigilance: Empowering vehicle safety with health alert technology addresses the risk of carbon monoxide (CO) poisoning in non-moving vehicles by providing early warning and initial emergency reaction itself, empowering users to take immediate action and activate safety features, thus mitigating the potential dangers of CO exposure. The main objectives of this project are to design a portable CO detection device for in-car use, simulate fail-safe mechanisms for activating safety measures in response to high CO levels, and create a user-friendly interface for easy access to CO detection and safety controls, utilizing ESP32 microcontroller, with a scope that includes circuit design, prototype development, and integration with the Blynk IoT platform. The study utilized standard materials, methods, and procedures to ensure accurate and reliable data collection. Key findings revealed the effectiveness of the CO system, with real-time measurements displayed on an OLED screen and additional safety features such as alarms and automated window-opening mechanisms. The discussion highlights the successful reduction of CO exposure risks through the integration of IoT technology, user-friendly interfaces, and safety mechanisms. Future work suggestions include further optimization and refinement of the CO detection system to enhance its performance and expand its applicability.

Keywords: Carbon Monoxide Detection, Vehicle Safety, Health Alert Technology, ESP32

1. Introduction

Carbon monoxide (CO) is an odorless and colorless gas produced by incomplete combustion of fuels by internal combustion engines, motor exhaust fumes, power plants and heating systems. World Health Organization (WHO) has established outdoor maximum CO levels at 90 parts per million (ppm) averaged over fifteen minutes. Once the gas is inhaled into the lungs, it binds preferentially with hemoglobin, displacing oxygen in the blood. The elevation of blood CO level inhibits oxygen uptake,

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depriving oxygen-demanding organs such as the brain and heart of sufficient oxygen. CO poisoning is a serious medical condition caused by the rise in the concentration of CO in the body. This condition is commonly reported in patients suffering from prolonged or high exposure to this gas, such as in firefighters, welders, diesel engine operators and motor-vehicle occupants. Exposure to this toxic gas can produce a variety of health problems depending on the CO concentration and health status of the patients. These symptoms ranged from fatigue and chest pain, respectively, in healthy and people with heart disease at low concentrations to confusion, nausea, impaired coordination and fatal at very high concentrations. In 2000, NHTSA's National Centre for Statistics and Analysis reported 3,7115 deaths involving motor-vehicle-related unintentional CO poisoning due to factors such as broken exhaust systems, prolonged engine running in stationary motor vehicles, and faulty heating systems [1]. These conditions can cause CO gas to accumulate in the vehicle compartment, endangering the occupants. Therefore, a system able to detect in-car CO levels and an automatic safety system must be developed to prevent unintended deaths.

The current state-of-the-art CO monitoring systems are priced between MYR 700 to MYR 20,000, making the products inaccessible to many. To address this problem, [2] proposed an embedded system comprising an MQ-7 gas sensor and an MQ135 air quality sensor to detect CO and carbon dioxide (CO2), respectively. This portable system is designed to alert its users with a buzzer if the levels have exceeded the set thresholds. There are differences in the threshold values used in different works. Although [3] considered a CO threshold of 25 ppm as the cut-off for the risk, the World Health Organization (WHO) reported an average of 70 ppm as the dangerous level for CO toxicity.

Meanwhile, [4] investigated the performance of the CO under varying environmental conditions and emphasized the importance of the sensor placement and positioning for the effective performance of the CO sensors. While most of this research used compact and inexpensive electronic platforms, such as different Arduino variants, for monitoring and control of the system, [5] developed a CO gas leak detection system for automobile applications using an 8-bit PIC16F84 microcontroller on-board system that has the advantage of using flash memory for high-level programming languages.

With the ever-increasing popularity of wireless communication and the Internet of Things (IoT) for real-time information transmission, wireless technology has been incorporated into automobile CO leakage detection systems. [6] demonstrated the use of Short Messaging Services (SMS) as a supplementary feature of CO detection to alert its users of the rise in the CO level detected at a remote location. [7] reported the continuous monitoring, collection, and storing of CO information on a cloud platform. This drastic growth in the database industry has seen remarkable advances in machine learning. Such work includes [8] integrated machine-learning techniques in the interpretation of the data collected in real-time.

Most of the above-mentioned works focused on the development of a portable CO detection and monitoring system without including life-saving measures. A straightforward and efficient strategy is to open the car window to allow better ventilation in the car compartment. SmartCOdetect is a recently developed system proposed in [9] that integrates a motor in the system for the activation of car windows. The workers demonstrated the use of Arduino Uno for transmission of warning alerts to its users through Global System for Mobile Communications (GSM) upon detecting the rise of CO to a dangerous level. The users were able to activate the window opening system remotely once they received the notification. Even though a remotely operated mechanism can reduce the mortality rate of its occupants, prompt and automatic response should be made when an emergency arises. In this study, we demonstrate a compact and scalable CO system for automatic toxicity prevention purposes. Section 2 discussed the development of the proposed portable system, followed by the results and analysis of the collected data in Section 3 which discussed the critical findings of the work before the concluding remarks in Section 4.

2. Materials and Methods

2.1 A system development and implementation

Figure 1 shows the designed circuit (left) and the developed prototype (right). This final prototype has an overall size of 5.5 cm × 4.5 cm × 9 cm. We used the MQ-7 device as the CO detector and the ESP32 board as the microcontroller to process output from the sensor due to its small footprint and availability of wireless communication protocols. This device is equipped with the built-in Wireless Fidelity (Wi-Fi) module for online transmission of data to the Blynk cloud server and rapid monitoring of CO levels. It is also connected with an Organic Light-Emitting Diodes (OLED) display and a buzzer for showing the real-time results on the display at the in-car passengers' end and alert the occupants in case of elevated CO. The chosen threshold for activation of the alert system is 70 ppm, in line with the standard recommended by the WHO. Under the condition when the CO level has exceeded the set threshold, Blynk would automatically send a push notification to the user's registered mobile phone.

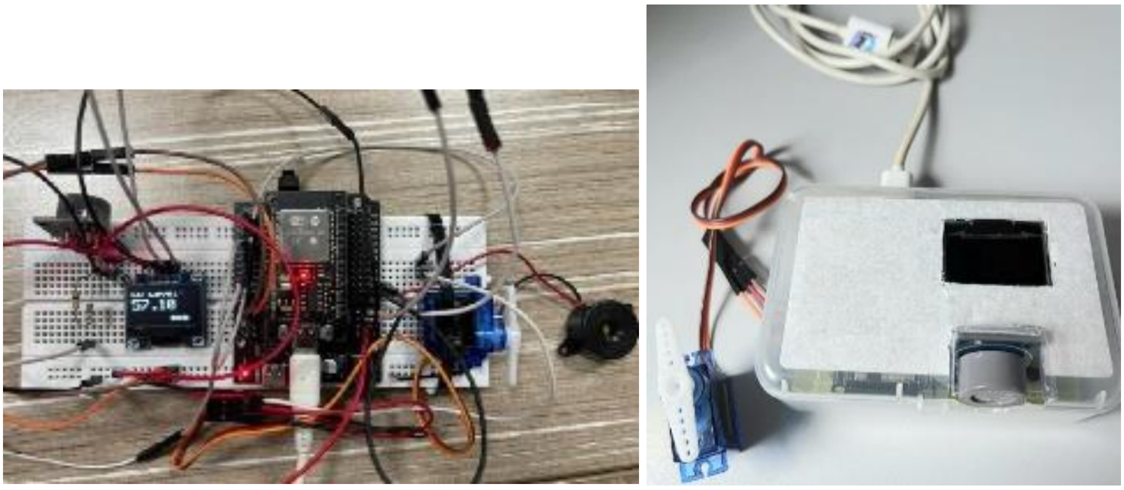

Figure 1: (Left) First working CO detection circuit on a breadboard. (Right) Final prototype with an enclosed case

Since the in-car CO leakage mostly originated from the fume's exhausts in the engine compartment venting to the passenger cabin through the air-conditioner system, the system was placed approximately 100 mm away from the dashboard air-conditioner vent. Even though alarm and notification messages would be sent to alert its users in case of emergency, the system must react promptly in supporting the occupants' safety as the highest priority. Thus, we integrated a lightweight micro servo motor (model no: SG90 9G) into the system to automatically activate the window openings. The motor is programmed to rotate to an angle of 45°, corresponding to the rolling down of a window by about 8 cm when the signal is given to it.

2.2 CO detection evaluation

This study performed three field experiments to investigate the functionality and sensitivity of the developed system tested under different operational and environmental conditions. The first is by examining the in-car CO levels under different vehicle mobility. In this experiment, CO levels were recorded inside the proper ventilation, enclosed space of the test vehicle Proton Saga (a) when it is in idle state, (b) during a long-distance haul, and (c) driving in heavy traffic. The second experiment is to investigate changes in the CO levels inside the immobile automobile under shades at different times of the day. The data were recorded each morning, noon, and evening at 0700, 1200, and 1800 hours, respectively, on three consecutive days. The average temperature recorded in these three days at 0700, 1200 and 1800 hours were 29°C, 35°C, and 38°C, respectively. The third is by inducing CO elevation in an enclosed space by burning charcoal inside a jar close to the CO sensor; the values were allowed to range from 70 ppm to 80 ppm controlled by limiting the sensor exposure time and its distance from its source for activation of the servo motor. The time taken for triggering the motor and the Blynk alert notification were recorded for three consecutive runs.

3. Results and Discussion

3.1 CO Vigilance: Empowering vehicle safety and technology system

Since the CO level is reported to vary with the automobile mobility and ambient temperature, we recorded the CO levels from the compartment when the test vehicle is idle, traveling on the highway, and congested conditions in Figure 2 (i.e., Different mobility test). The ambient temperature test represents the data recorded inside the passenger cabin of an idle car with a running engine at different times of the day (i.e., morning, noon, and evening) for three days. The relationship between the automobile mobility status and in-car CO level is tested using a *t*-test in SPSS Statistics Ver 23. The same test is also performed for the correlation between ambient temperature and the CO concentration. The analysis revealed statistically insignificant results with ρ values of .168 and .125 with a significance level of 0.05 for mobility and ambient temperature test, respectively, suggesting the null hypothesis is accepted and there is a significant influence between the CO concentration and the investigated factors.

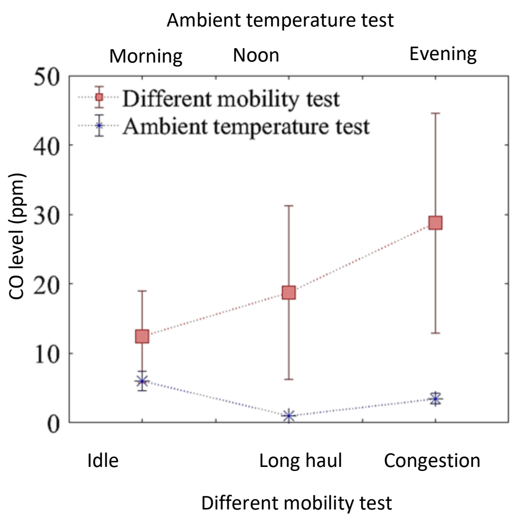

Figure 2: A graph of CO levels from the compartment according to several conditions

We also compared our findings with the values reported in prior studies in Table 1. While the average sampling time of the CO sensor is 2 seconds (s), the mean and standard deviation (SD) response time for activation of the motor and Blynk notification alert were recorded as 26 ± 3 s and 8 ± 3 s. Since the sensing of the CO level is not in real-time, the recorded CO levels for motor activation (window opening) and reverse activation (window closing) as the CO source was removed are shown in Figure 3.

Table 1: Time taken to activate safety feature after being exposed to specified CO level and sends an alarm to the user

Item	CO level	Time taken to activate the safety feature (sec)	Time taken for blynk to send alert to its user
1	70	7	5
2	80	5	7
3	90	3	8
4	100	1	10
5	110	4	12

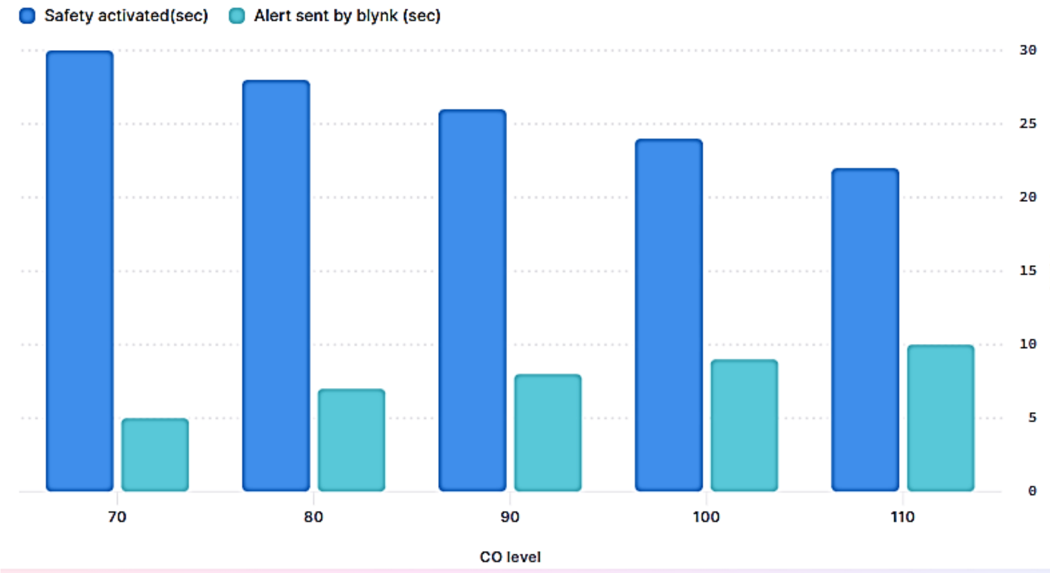

Figure 3: A graph of CO level versus safety feature activation

As CO levels rise, the time it takes for the CO detector's safety function to activate reduces. This shows that the detector gets more sensitive to increased carbon monoxide concentrations. Speed of Safety Mechanism Activation: When stationary, the CO detector responds quickly, triggering its safety mechanism within seconds of being exposed to excessive CO levels. This quick activation is critical for delivering timely warnings and safeguarding people from potential damage. The data shows that once the safety function is engaged, the CO detector rapidly delivers an alarm to the user. The alarm is sent in 5 to 10 seconds, providing that consumers receive timely notification of the existence of elevated CO levels.

4. Conclusion

In conclusion, the CO Vigilance system offers a comprehensive solution for ensuring vehicle safety and mitigating the risks of carbon monoxide (CO) exposure. By utilizing Internet of Things (IoT) technology and the Blynk application, the system provides remote monitoring and user notifications. The inclusion of an OLED display enables real-time CO level measurements, enhancing user convenience. The system incorporates safety features such as alarms and automated window-opening mechanisms to respond promptly to high CO levels. The CO Vigilance system effectively reduces the risk of CO exposure within vehicles, protecting the health of occupants. The study demonstrates optimal performance during morning and noon hours, with a working range of up to 10 meters. The safety features activate within 22 to 30 seconds, depending on the ambient CO levels. Overall, the CO Vigilance system significantly enhances passenger safety by integrating IoT technology, a user-friendly interface, and safety mechanisms to address the dangers associated with CO exposure. To further improve the effectiveness and reliability of CO detectors, it is recommended to focus on two key areas. Firstly, implementing long-term performance monitoring methods, such as regular calibration and maintenance, ensures ongoing precision and dependability. Secondly, fostering collaboration among regulators, manufacturers, and researchers is crucial for establishing uniform testing practices and performance standards across all CO detector devices. Additionally, conducting a comparative study between the CO Vigilance system and existing CO detectors would provide valuable insights into its performance and reliability. These recommendations aim to enhance CO detection technology, elevate safety standards, and protect individuals from the dangers of CO exposure.

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