IoT-based Carbon Monoxide (CO) Real-Time Warning System Application in Vehicles

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Abstract. The project is about developing a system and application for detecting the presence of Carbon Monoxide (CO) in the car, with recently there are many cases of drowning while sleeping in car due to inhaling CO. The system is able to detect the presence of CO and provide a warning about the level of CO to the users. It uses the Blynk application to monitor the level of CO inside the vehicle, MQ-9 gas sensor as the input sensor, ESP 8266 as a medium to send data to the application via IoT-based, and the level concentration of CO is displayed on the LCD in real-time. For the output, it has three different conditions based on the level concentration of CO. This project has been tested in six different situations. Based on the results, the air in the car with an open window situation has the lowest concentration of CO. Meanwhile, the highest concentration of CO is detected in smoke produced from fuel combustion of the car exhaust at a distance of 5 cm. Additionally, Principal Component Analysis (PCA) is used to analyze the ability of this system in clustering for each situation. As a result, PCA has clearly clustered the data for each situation with PC1 accounting for 71.82% and PC2 for 28.18%, hence it is verified that the developed system is able to apply in detecting the presence of CO. This project is believed to help reduce the number of cases of people drowning while sleeping due to inhaling CO in the car.

1. Introduction

There were many cases reported of teenagers drowning while sleeping due to inhaling CO in the car whose engine was turned on. For example, one of the teenagers found dead in the car at Kampung Jaya Baru, Kinabatangan, Sabah on 11 October 2018 [1]. There are also cases reported from abroad on 19 March 2020 and 5th October 2020 which also involves teenagers dying in cars due to CO poisoning [2, 3]. While the latest case happens in Butterworth, Penang involving, four students taking a nap inside the car resulting in three of them have died due to CO poisoning [4].

CO is a mixture of one element carbon and one element oxygen which is a colourless, odourless and tasteless toxic gas [5]. CO is toxic to humans when found in high concentrations as it causes disorders in the...
blood. This case occurs because there is no specific device to assist in monitoring the level of CO and warn from time to time (real-time) in vehicles especially for cars. By respect to all this problem occurred, a system or device that are able to monitoring the presence of hazardous gasses are much appreciated. Hence, this research is aimed in developing a system that can give information as well as monitoring level of CO inside the vehicles such as a car and sending a notification if there have any dangerous situation occurred. This device or system is believed can give benefits for users, mostly for teenagers as well as for their parent for monitoring purpose since it can be access through smart phones.

From the Table 1 below, there are few symptoms that can detect based on CO level of concentration and length of exposure. This also used to consider limit of the sensor and for making decision of the output. The risk to health of CO poisoning also can be measured by time weighted permissible exposure limit. For example, Occupational Safety and Health Administration (OSHA) have recommended time weighted permissible exposure limit (PEL-TWA) of 50 PPM. Besides that, National Institute for Occupational Safety and Health (NIOSH) have recommended exposure limit (REL-TWA) of 35 PPM. Furthermore, Iran Health Ministry have recommended occupational exposure limit (OEL-TWA) of 25 PPM. This also need to be considered in making decision for the output for this project [9],[10].

### Table 1. Symptoms based on CO level and length of exposure.

| CO level (PPM) | Time  | Symptoms                                                                 |
|---------------|-------|--------------------------------------------------------------------------|
| 35            | 8 hours | Maximum exposure allowed by OSHA in the workplace.                       |
| 200           | 2-3 hours | Fatigue, mild headache, nausea and dizziness.                            |
| 400           | 1-2 hours | Serious headache and life treating after 3 hours.                        |
| 800           | 45 min  | Vertigo, nausea and convulsions. Unconscious within 2 hours. Death within 2-3 hours |
| 1600          | 20 min  | Headache, vertigo and nausea. Death within 1 hour.                      |
| 3200          | 5-10 min | Headache, vertigo and nausea. Death within 1 hour.                      |
| 6400          | 1-2 min  | Headache, vertigo and nausea. Death within 25-30 minutes.               |
| 12800         | 1-3 min  | Death                                                                    |

2.1 Methodology

2.1 Flowchart of the project

The process of this project is shown below in Figure 1 while Figure 2 shows the LCD shows the CO level and it condition which is medium. The project is starting by collecting data via sensor that have been used in the system. After that, the data is sends to the Blynk application for monitoring purpose and the system will make future action based on the level CO that have been collected. Next, the data stores in Google Sheets every 5 seconds. The data that have been stores can be used to analyse the project functionality. Lastly, the data will be clustering or grouping by using PCA.
2.2 Flowchart of the system
Overall, the system consists of three operations which are the input sensor, processing unit, and output. The system uses MQ-9 sensor as the input sensor in which to detect the level of CO gas and passes the output voltage to the Arduino Uno for process. The output voltage is converted to concentration of CO in PPM by using program code that has written. The LCD acts as a monitor to display the concentration of CO level in real-time which is in every 5 seconds.

As referring to Figure 3, the system starts by reading the CO level. Next, the microcontroller will do a calculation of CO level. After that, the reading of CO level will be display using LCD in real-time and all the data will be sent to the application. The concentration of CO will be determine using the application. As a result, it will trigger the certain output such as trigger the alarm, light the bulb, lower the car window(presented by servo motor) and sends notification based on the condition that has been decided. More details, the output consists of three conditions based on the concentration of CO as per described below:
- If the PPM of CO lowers than 25 PPM, then there is no action from the system.
- If PPM of CO is between 25 PPM until 199 PPM, then it will trigger alarm only.
- If the PPM is 200 PPM and above, then it will trigger alarm, light the bulb, lower the car window that presented by the servo motor and notify the users using application. The alarm will keep warn continuously and the notification will send to the mobile phone via Blynk application.

Figure 4 shows the connection of the components that consists of NodeMCU, MQ-9 gas sensor, buzzer, LED, LCD, servo motor and resistor.
3. Results and discussions

The CO level that sense by the MQ-9 sensor has been displayed on the LCD. On the LCD, it not only shows the CO level but it also shows the condition for situation based on CO level whether it is low (0 PPM until 24 PPM), medium (25 PPM until 200 PPM) or high (more than 200 PPM). The condition whether it is low, medium or high will affect the output part which is alarm (buzzer), bulb of inside car (led), lower window (servo motor) and notify using application as shown in Table 2.

**Table 2. PPM range and output part for every condition.**

| Condition | Output Part                                      | PPM range     |
|-----------|--------------------------------------------------|---------------|
| Low       | • No action                                      | 0 until 24 PPM|
| Medium    | • Alarm (buzzer) triggered                       | 25 until 200 PPM|
| High      | • Alarm (buzzer) is trigged                      | More than 200 PPM|
|           | • Bulb of inside car (led) turns on              |               |
|           | • Lower the car window (servo motor)             |               |
|           | • Notify using application                       |               |

**3.1 Blynk Application**

For the monitoring, it can be access by using application which is Blynk application that supported by Android mobile phone. In this application, it will show CO level in real-time same as it shows on the LCD. Besides that, this application also shows the graph of CO level in real time and also for a certain period that can choose by the user. This monitoring system that can access through this application also can be monitor by third-party users such as parent or other family member.

Furthermore, data collected is stored in Spreadsheet which can be access by using mobile phone or using other devices such as tablet or laptop. This stored data can be used for references or evidence if there are any undesirable incident cause by the high CO level in the car. The monitoring system by Blynk application and store data by Spreadsheet are based on IoT mechanism that very useful for humans especially for the users.
3.2 Analysis of the result

The result of this project has been collected in different situation such as in ambience air, in car with open window, in car with close window, in car while the air conditioner is turn on and smoke that are produce from fuel combustion of the car exhaust. From the Table 3 below, there shown all result that have collected in different situation that been stated.

Table 3. Condition and output for every situation.

| Situations                                           | CO level (PPM) | Condition | Output                                               |
|------------------------------------------------------|----------------|-----------|------------------------------------------------------|
| Ambience air                                         | 1-5            | Low       | No action.                                           |
| In car with open window                               | 1-2            | Low       | No action                                             |
| In car with close window                              | 2-3            | Low       | No action                                             |
| In car while the air conditioner is turn on           | 2-3            | Low       | No action                                             |
| Smoke that are produce from fuel combustion of the car exhaust (distance 5 cm) | 206-245        | High      | Trigger alarm, light the bulb, lower the car window (servo motor) and notify using application |
| Smoke that are produce from fuel combustion of the car exhaust (distance 30 cm) | 24 - 34        | Medium    | Triggered alarm                                      |

Based on Figure 5 and Figure 6, in ambience air and in car with open window situation it has same lowest reading of CO level. However, for the highest reading of CO level, in ambience air has higher CO level compared to in car with open window situation. This is because it is affected by the environment of the places. It is possibly when data collected in ambience air, there are several vehicles passing by in the area.

For in car with close window and in car while the air conditioner is turn on, both situations give same result for lowest and highest of CO level. Both situations have reading of CO level a little bit higher compared to in car with open window situation. This is because when in confined space, the CO gas that enter before the window close will be trapped inside car. But this does not endanger the health of the users. For the four condition that has been interpret before this, it can be classified as low condition of CO level.

On the other hand, smoke that are produce from fuel combustion of the car exhaust at distance 30 cm, have mid-range CO level reading. This can be categorized as medium condition of CO level. In this condition, health of users may be risk when long exposed in that situation based on World Health Organization (WHO) CO level exposure limits [8]. Last but not least, smoke that are produce from fuel combustion of the car exhaust at distance 5 cm have the highest reading CO level compared to all situation. This situation can be classified as high condition CO level. If this smoke enters inside the car because of leaking from the exhaust or the engine, this can be harmful for the drivers and passengers. By referring to data collected in Table 2 also, it can be related with maximum exposure allowed by OSHA for CO level. The maximum CO level that allowed by OSHA is 35 PPM as in Table 1. According to this maximum CO level that allowed by OSHA, the smoke that are produce from fuel combustion of the car exhaust in distance 5 cm is dangerous. The CO level in that situation is higher than 200 PPM for both lowest and highest reading of CO level from data collected in field test. This can cause fatigue, mild headache, nausea and dizziness as stated in Table 1 if the smoke enters inside the car. It will also be worsened if the driver or users is not aware of this so it can cause the users drown and die due CO poisoning.
Meanwhile, Figure 7 shows graph about time sampling against PPM for every situation except for smoke of fuel combustion of the car exhaust at distance 5 cm and at distance 30 cm. Then, Figure 8 show graph about time sampling against PPM for every situation. Both figures illustrate the collected data in sampling data of every 5 seconds. In these two figures, clearly show that the smoke from fuel combustion at 5 cm and 30 cm have higher reading compared to other situations.

Therefore, this project is very useful to overcome this dangerous situation as well as can reduce the number of humans died causes of CO. This project has a system that can detect and give warning about the level of CO to the users. In this situation, the system will send signal to alarm (buzzer) to trigger it. Besides that, lamp (led) inside the car will automatically turn on and the window of the car will also automatically lower. This can notice and attracting the attention of those in surrounding about this situation. This will make it easier for people to help if the situation is detrimental such as the driver fainting, sleeping or drowning in the car. In addition, Blynk application that has been used in this project will also send warning to their parents or other family members. So, their parent or family members can monitor the CO level which can threaten life or not. This is one of advantages for this project that used IoT-based system which is have integration between the devices and the system by using the Internet.

**Figure 5.** Lowest reading of CO level for every situation.

**Figure 6.** Highest reading of CO level for every situation.

**Figure 7.** Graph about time sampling against PPM for every situation except for smoke of fuel combustion of the car exhaust at distance 5 cm and at distance 30 cm.

**Figure 8.** Graph about time sampling against PPM for every situation.
3.3 PCA

PCA were applied in order to verify the ability of this CO system in differentiate or clustering these 6 situations. Figure 9 shows the scatter plot of PCA of every situation that involved in this project. The first PC is yield 71.82% accounted for the biggest variance while the second PC is 28.18%. It clearly shows the situation of smoke fuel combustion of 5cm and smoke fuel combustion is clearly separated with each other as well as separated with ambience, air condition turns on, car close window and car open window. Ambience, air condition turns on, car close window and car open window look like overlapping each other since it can be considered very low in CO presence.

However, the PCA plot were tested by eliminating the data of smoke fuel combustion of 5cm and 30cm. Next, Figure 10 shows the scatter plot of PCA of every situation except for smoke of fuel combustion of the car exhaust at distance 5 cm and at distance 30 cm where the first PC is 86.64% and the second PC is 13.16%. By comparing the result, it clearly shown that each situation is clearly grouped. This result indicates and proved that the CO system are able to differentiate every situation by respect to the value of CO. This is meant that the MQ-9 gas sensor with the build system are able to be applied in detecting the presence of CO in different situation.

![PCA plot every situation of the collected samples.](image1)

![PCA plot of every situation except for smoke of fuel combustion of the car exhaust at distance 5 cm and at distance 30 cm.](image2)
4. Conclusion
This IoT-based Carbon Monoxide (CO) Real-Time Warning System Application in Vehicles project are very useful to all car driver. This project is a system that integrates hardware with IoT. This system is capable of being the greatest solution for the problem of CO gas poisoning in vehicle especially car due to its real-time concept and use of IoT technology. It is envisaged that this system will decrease the number of people who die caused of CO poisoning in car.

The system is well designed for detection and give warning about CO level to the users by its hardware part which is consists of MQ-9 gas sensor, LCD, buzzer and other components. Besides that, this project was also successful in designing Blynk application to monitor level of CO for the vehicles especially car.

Furthermore, this project was achieved to integrated the monitoring and warning system with IoT – based. This can be proven by the relationship between the hardware parts and the application including storing data online in Spreadsheet and also the notification from the Blynk application about the CO level. Last but not least, PCA have clearly clustering data for every situation with the value of each PC is quite high, hence it verified that the build system is able to applied in detecting the presence of Carbon Monoxide.

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