Mobile Carbon Monoxide Monitoring System Based on Arduino-Matlab for Environmental Monitoring Application

Nur Azieda Mohd Bakri, Syed Abdul Mutalib Al Junid*, Abdul Hadi Abdul Razak, Mohd Faizul Md Idros, Abdul Karimi Halim
Centre for Electronics Engineering Studies,
Faculty of Electrical Engineering, Universiti Teknologi MARA,
Shah Alam, Selangor, Malaysia
E-mail: samaljunid@salam.uitm.edu.my

Abstract. Nowadays, the increasing level of carbon monoxide globally has become a serious environmental issue which has been highlighted in most of the country globally. The monitoring of carbon monoxide content is one of the approaches to identify the level of carbon monoxide pollution towards providing the solution for control the level of carbon monoxide produced. Thus, this paper proposed a mobile carbon monoxide monitoring system for measuring the carbon monoxide content based on Arduino-Matlab General User Interface (GUI). The objective of this project is to design, develop and implement the real-time mobile carbon monoxide sensor system and interfacing for measuring the level of carbon monoxide contamination in real environment. Four phases or stages of work have been carried out for the accomplishment of the project, which classified as sensor development, controlling and integrating sensor, data collection and data analysis. As a result, a complete design and developed system has been verified with the handheld industrial standard carbon monoxide sensor for calibrating the sensor sensitivity and measurement in the laboratory. Moreover, the system has been tested in real environments by measuring the level of carbon monoxide in three different lands used location; industrial area; residential area and main road (commercial area). In this real environment test, the industrial area recorded the highest reading with 71.23 ppm and 82.59 ppm for sensor 1 and sensor 2 respectively. As a conclusion, the mobile real-time carbon monoxide system based on the Arduino-Matlab is the best approach to measure the carbon monoxide concentration in different land-used since it does not require a manual data collection and reduce the complexity of the existing carbon monoxide level concentration measurement practise at the same time with a complete data analysis facilities.

1. Introduction
Nowadays, the level of carbon monoxide concentration has become global issues since it produced a bad effect and harms the environment globally. A series of conference and symposium are organized all over the world to discuss and find the solution for the increasing of the carbon monoxide issue. New policy and convention are introduced as an outcome from the meeting, but it cannot solve the issue as the whole since the implementation required an agreement on the country law by itself. But, their findings on the main contributory factor of carbon monoxide contamination have produced a good guideline for each of the countries on the source of the pollution towards design and implement their own law and guidelines control the pollution. The industrial area and transportation have been
identified as a major contributor for the carbon monoxide released which contaminate the air globally and it has been confirmed by the inmost of the report and publications [1]-[2].

In Malaysia, transportation has been identified as one of the major contributing factors for air pollution with corresponding to the increasing numbers of vehicles in major cities in Malaysia from year to year [2]. In 2011, the total numbers of registered vehicles on Malaysia road have passed 21.25 million units as reported in [1]. The data was supported by the estimation of air pollutant emission load in 2008 with 1.45 million metric tonnes of carbon monoxide concentration have been released [3]. On the other hand, the carbon monoxide is a poisonous gas that is colourless, odourless and tasteless, which is produced by a product of combustion, which is impossible to detect by the exposed person [4]-[5].

In health perspective, carbon monoxide reduces the flow of oxygen in the bloodstream and is particularly dangerous to persons with heart disease [2]. At the high level of carbon monoxide concentrations, it can impair vision and coordination, such as headaches, dizziness, confusion, nausea and also can cause flu-like symptoms. While at low level carbon monoxide concentrations, it can fatigue in healthy people and chest pain in people with heart disease and other lung related disease [7]. Over 500 people killed and more 20,000 people are sent to the hospital each year due to the effect of carbon monoxide gas in environment as reported in [7].

The situation will remain until the continuous monitoring for observing this scenario has been enforced and the high penalty rules implemented. The Real-Time carbon monoxide monitoring system is one of the best solutions to determine the level carbon monoxide concentration in a large scale area which capable to plot the area which contribute to the high level of the carbon monoxide content [8]. This will help in plotting the region or location of the carbon monoxide on Geographical Information System (GIS) which are currently used for controlling and observing the environmental issues globally.

Although several solutions have been proposed to monitor the environmental issue previously in [9]-[10] but, it focuses more on the measuring the thermal comfort issue which resulted from the carbon monoxide effect and improper land used development. Considering the global solution for the proposed design, a low cost controller based on the open source electronics prototyping platform will be used as the controller in the project, which has been reported used widely in environmental and prototyping projects in [10]-[13].

The report is organized in five important sections with the overview of the project is highlighted in section 1. Section 2 will be brief the method or process of accomplishment of the design, development and test of the proposed project. The details result of the implementation will be reported in Section 3 while the discussion of the finding will be detailed elaborated in the next section. The last section or section 5 will conclude the all the finding of the project.

2. Methodology of design
Four phases of work have been used to accomplish the project until the implementation of the system in real environment. It starts with the development of sensor system for sensing the carbon monoxide gas concentration and followed by controlling and integrating the sensor with an Arduino UNO microcontroller. The third phase focussed on the process of data collection and the final phase of work emphasis on the data analysis measured and recorded using the proposed system in the real environment. The details of each phase are explained in the subsequent sections.
2.1. Sensor development
There are three stages have been carried out in the sensor development stage, which is the calibration of carbon monoxide sensor, module starter kit for Global Positioning System (GPS) and development of sensor circuit

2.1.1. Calibration of carbon monoxide sensor

![Figure 1. Carbon Monoxide sensor (MQ-7)](image)

Figure 1 shows the MQ-7 carbon monoxide sensor that has been used in the project. The calibration of sensor reading was done by referring to the MQ-7 carbon monoxide sensor datasheet. Moreover, the calibration of the sensor also required a complete reference to the level of carbon monoxide in Atmosphere (in parts per million) as shown in Table 1 for relate the sensor readings obtained precisely. However, the exposure to the carbon monoxide required high precaution and need be avoided because it gives various unhealthy effects and the detailed effects is summarized in Table 2 [15].

| Level of Carbon Monoxide | Source                                      |
|--------------------------|---------------------------------------------|
| 0.1 ppm                  | Natural atmosphere level                     |
| 0.5 to 5 ppm             | Average level in homes                       |
| 5 to 15 ppm              | Near properly adjusted gas stove in homes    |
| 100 to 200 ppm           | Exhaust from automobiles in the city         |
| 5000 ppm                 | Exhaust from a home wood fire                |
| 7000 ppm                 | Undiluted warm car exhaust without a catalytic converter |

| Level of Carbon Monoxide | Source                                      |
|--------------------------|---------------------------------------------|
| 35 ppm (0.0035%)         | Headache and dizziness within six to eight hours of constant exposure |
| 100 ppm (0.01%)          | Slight headache in two to three hour        |
| 200 ppm (0.02%)          | Slight headache within two to
three hours; loss of judgement

| Concentration (ppm) | Effect                          |
|---------------------|--------------------------------|
| 400 ppm (0.04%)     | Frontal headache within one to two hours |
| 800 ppm (0.08%)     | Dizziness, nausea, and convulsions within 45 min; insensible within 2 hours |
| 1600 ppm (0.16%)    | Headache, tachycardia, dizziness, and nausea within 20 min; death in less than 2 hours |
| 3200 ppm (0.32%)    | Headache, dizziness and nausea in five to ten minutes. Death within 30 minutes |
| 6400 ppm (0.64%)    | Headache and dizziness in one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes |

2.1.2. **SKM53 GPS Module starter kit**

Figure 2 shows the GPS module starter kit used in this project. The SKM53 series with the embedded GPS antenna enables high performance navigation in the most stringent applications and solid fix even in harsh GPS visibility environments. It is specially designed starter kit which offer convenient yet safer GPS module for user. Moreover, the supply is from 5V of UART pin with operating temperature range from -40°C to 85°C. The SKM53 GPS module has ultra-high tracking sensitivity within -165dBm extends positioning coverage into place like urban areas and dense foliage environment where the GPS was not possible before. The SKM53 also used NMEA protocols which is a simple device generating NMEA sequence for testing embedded GPS reception firmware and hardware is described [16]. The device can work in standalone mode and also in conjunction with control software. Configuration program can be used to generate test strings without tester hardware as well as stated in [16].

2.1.3. **Development of sensor circuit**

The MQ-7 carbon monoxide sensor with simple drive circuit is used to detect the presence of carbon monoxide (CO) gas in this project. The sensor has been chosen because it has high sensitivity to carbon monoxide and is widely used in industrial for a CO detector. The circuit construction and position of the sensor is very important for obtaining the reading of carbon monoxide level at this stage.

2.2. **Controlling and Integrating Sensor**

The second stage involved in this project is controlling and integrating the carbon monoxide sensor with the microcontroller. This phase is divided into two parts which is hardware development and software development.

2.2.1. **Hardware development**

In this part, two carbon monoxide sensors and GPS are combining with the embedded system at the first step. The purpose of the two carbon monoxide sensors were used is to make sure the accurate reading obtained since the operation of the sensors required pre-heat process for every reading or measurement. Next, both of the sensors and GPS is configured for reading the latitude and longitude
of the GPS and level concentration CO sensor via the serial monitor of the microcontroller. The position of the reading obtained from the serial monitor is important since the data is very important and required when interface with the software part. The carbon monoxide sensors and GPS are supplied with 5V Direct Current (DC) which source from the Arduino UNO. The complete explained system architecture is illustrated in Figure 3.

2.2.2. Software development

General User Interface (GUI) MATLAB is used in the project for development of the real time monitoring activity since it has a graphical display in more than one window and the user can use it to perform more interactive tasks. In addition, MATLAB version used in the project is 2011b with the Arduino interface package or tool box. Figure 4 shows the illustration of GUI MATLAB with the graphical representation for plotting the data.

The reading obtained from the carbon monoxide sensors were viewed in the graphical representation. Moreover, the plot handles are used where the system started to illustrate the reading from the microcontroller. Besides that, the results from sensors obtained are displayed in the numeric value for ease the user to read the data. On top of that, the real-time graph with the interval changes are embed together with the sensor reading to ease the analysis of the measurement. The signal detected from GPS plotted the coordinates of latitude and longitude of the in the GUI. Besides that, there is a save handle that link to the Microsoft Excel as shown in Figure 5. The function is to save all data obtained during the process of collecting data to the Microsoft Excel format for further analysis.
2.3. Data collection

In the third stage, the data collection was conducted to verify and validate the system. A complete monitoring activities have been conducted at this stage. The monitored area is Industrial Area, Residential Area and main road (commercial area). Every area is being monitored within three minutes and every second data will be recorded and saved in data logger.

Figure 6 shows the integration of carbon monoxide Sensor 1 and Sensor 2 to the monitoring facilities and it was positioned on top of the monitoring vehicle. The carbon monoxide sensor 1 and sensor 2 are placing about 40cm apart from each other as shown in the Figure 6. The purpose of placing two sensors is to observed data in more accurate and precise ways. The GPS module also has been positioned at the monitoring facilities. It is due to open space and clear sight which required by the GPS module in order to find the satellite connection and get the coordinates of the monitored area without interruption. Figure 7 shows the equipped mobile monitoring facility on top of the monitoring vehicle. Figure 8 shows the Real-Time Host (GUI MATLAB) placed inside the monitoring vehicle. Every recorded data and the changes will be displayed in real-time graphical representation.
2.4. Data analysis
Data analysis will be the final stage of work which involved analysis of sensor readings. The level of carbon monoxide in each monitored area will be carefully recorded and systematically analysed.

3. Result
The results of the monitoring process consist of three parts which is the maps (from MATLAB) that locate the observed area, the graphical representation of the carbon monoxide concentration level in each monitored area and analysis of tabulated data of carbon monoxide profiles. Each of the components will be detailed discussed in its respective sub-sections.

3.1. Maps Locate the monitored area
The monitoring activities has been done to observe the level of carbon monoxide in three different areas. Figure 9 shows the example coordinates locate by the GPS module in real-time during the monitoring activities. The mapping location data were recorded from the starting point up to the ending point of monitoring areas.

![Figure 9](image1.jpg)  ![Figure 10](image2.jpg)

Figure 9. Latitude and longitude coordinates are located by the GPS.  Figure 10. Industrial area mapping point

Figure 10 shows the mapping point of the monitored Industrial area. The location is at Kawasan Perusahaan Bandar Sultan Suleiman, Klang, Selangor. It starts from 166, Solok Sultan Mohamed 1 and ending at 19, Lebuh Sultan Mohamed 2. The duration of monitoring activities was set at 3 minutes. This area has been chosen due to the numbers of factories and the routes for trucks and trailers. The level carbon monoxide concentration is expected to be higher due to the reasons.

Figure 11 shows the mapping point of the monitored residential area. The location is at at Jalan Platinum, Seksyen 7, Shah Alam, Selangor. The point starts from Jalan Platinum 7/59, Seksyen 7 and ends at Jalan platinum 7/60, Seksyen 7. This location has been chosen due to the populated area.
Figure 12 shows the main road (commercial area) mapping point which has been chosen to be observed in this monitoring activity. The location is at Seksyen 7, Shah Alam which is the main road for residents and community. The observation point starts from Persiaran Permai Seksyen 7 and ends at Lebuh Keluli, Seksyen 7.

3.2. Graph of Carbon Monoxide concentration in each monitored area.

Figure 13. Carbon monoxide concentration in industrial area.

Figure 14. Carbon monoxide concentration in residential area.

Figure 15. Carbon monoxide concentration in main road (commercial area)
Figure 13, Figure 14 and Figure 15 shows the graph of carbon monoxide concentration for each of the monitored areas during monitoring activities. The graph is plotted based on data recorded by both of the carbon monoxide sensors.

3.3. Carbon monoxide data analysis

| Monitored Area | Sensor 1 (ppm) | Sensor 2 (ppm) |
|---------------|----------------|----------------|
| Industrial    | 71.23          | 82.69          |
| Residential   | 28.38          | 35.40          |
| Main Road     | 44.10          | 35.40          |

Table 3 shows the average reading of carbon monoxide concentration recorded by both of the sensors in the monitored area. The highest average reading recorded in the Industrial Area with 71.23 ppm and 82.67 ppm for sensor 1 and sensor 2 respectively. The main road (commercial area) recorded the average of 44.10 ppm for sensor 1 and 35.40 ppm for sensor 2. The residential area recorded the lowest reading with 28.38 ppm and 35.40 ppm for sensor 1 and sensor 2 respectively.

4. Discussion

Carbon monoxide concentrations in three different areas have been measured and recorded during the monitoring activities. Industrial area recorded the highest average of carbon monoxide concentrations reading compared to others monitoring area. Smoke from factories and vehicle exhaust are the two major factors has been identified influence the reading. Besides that, the residential area recorded the lowest average of carbon monoxide concentration. The effect of tree planting around the housing estate may lead to lower the level of carbon monoxide emission in air while less source of air pollution compared to the industrial area can be considered as the main factor as well. The main road (commercial area) that has been observed in monitoring activities also recorded higher average of carbon monoxide concentration, it may due to the numbers of motor vehicles and traffic flow conditions passing through this area.

5. Conclusion

As a conclusion, the real-time mobile carbon monoxide monitoring system based on low cost microcontroller and interface to General User Interface (MATLAB) provides and offers a real-time and accurate carbon monoxide concentration monitoring for application in environmental monitoring. Moreover, the systems record accurate real-time data based on the industrial requirement and capable to work in a real environment. Besides that, the application of Global Positioning System (GPS) provides the accurate location of the monitored area complete with the measurement of carbon monoxide concentration. This will help to provide the accurate location of carbon monoxide concentration clearly for enforcement purposes.

Acknowledgments

Authors wishing to acknowledge Faculty of Electrical Engineering, Universiti Teknologi MARA for providing the financial support and facilities until completion of the project.

6. References

[1] Azmi, M., Saman, M. Z. M., Sharif, S., Zakuan, N., & Mahmood, S. 2006 Proposed Framework for End-Of-Life Vehicle Recycling System Implementation in Malaysia.
[2] Shuhaili, A., Fadzil, A., Ihsan, S. I., & Faris, W. F. 2013. Air Pollution Study of Vehicles Emission In High Volume Traffic: Selangor, Malaysia As A Case Study. WSEAS Transactions on Systems, 12(2), 67-84

[3] Choong, J. S. S. 2010. Conceptualization of Perceived Utilization of Public Bus Transport Service: Empirical Evidence for Malaysia Transport Sustainability (Doctoral dissertation, Universiti Sains Malaysia).

[4] Raub, J. A., Mathieu-Nolf, M., Hampson, N. B., & Thom, S. R. (2000). Carbon monoxide poisoning—a public health perspective. Toxicology, 145(1), 1-14.

[5] Nelson, V. C. (2011). Introduction to renewable energy. CRC press.

[6] Hamzah, N., Othman, K. A., & Zabidi, A. N. Z. M. (2013). Monitoring Carbon Monoxide Emission in the Air Using Wireless Application. In Proceedings of the World Congress on Engineering (Vol. 2).

[7] Voogt, J. (2007). How researchers measure urban heat islands. In United States Environmental Protection Agency (EPA), State and Local Climate and Energy Program, Heat Island Effect, Urban Heat Island Webcasts and Conference Calls.

[8] The Malaysian Times, "Global warming, a warning to all: The Malaysian Times," 30 July 2012. [Online]. Available: http://www.themalaysiantimes.com.my/. [Accessed December 2013].

[9] Rashid, Z.A., Al Junid, S.A.M. 2014. “Trees’ cooling effect on surrounding air temperature monitoring system: Implementation and observation.” International Journal of Simulation: Systems, Science and Technology 15 (2): 70-77.

[10] Amiruddin, A.I.A., Al Junid, S.A.M., Osman, F.N., Thani, S.K.S.O. 2014 “Real-time mobile microclimate monitoring system using labview RT.” International Journal of Simulation: Systems, Science and Technology 15 (2): 91-97.

[11] Othman, N.; Manan, M.I.A.; Othman, Z.; Al Junid, S.A.M. 2013. “Performance analysis of dual-axis solar tracking system,” in Control System, Computing and Engineering (ICCSCE), 2013 IEEE International Conference on , vol., no., pp.370-375

[12] Tahir, N. A. M., S. A. M. Al Junid, Z. Othman, Z. Abd Majid, and S. K. S. O. Thani. 2012. "Design Automatic Meter Reading (AMR) Data Logger with Xbee." International Journal of Simulation: Systems, Science and Technology 13 (1): 67-73.

[13] Usddek, M. E. M., S. A. M. Al Junid, Z. A. Majid, F. N. Osman, and Z. Othman. 2013. "High-Sensitivity Gas Detection and Monitoring System for High-Risk Welding Activity.”. doi:10.1109/SPC.2013.6735143.

[14] Husin, R., S. A. M. Al Junid, Z. Abd Majid, Z. Othman, K. K. Md Shariff, H. Hashim, and M. F. Saari. 2012. “Automatic Street Lighting System for Energy Efficiency Based on Low Cost Microcontroller." International Journal of Simulation: Systems, Science and Technology 13 (1): 29-34.

[15] Milton, R., & Steed, A. (2007). Mapping carbon monoxide using GPS tracked sensors. Environmental monitoring and Assessment, 124(1-3), 1-19.

[16] Sinivee, V. (2010). Simple yet efficient NMEA sentence generator for testing GPS reception firmware and hardware. In Novel Algorithms and Techniques in Telecommunications and Networking (pp. 207-210). Springer Netherlands.