

# Real-Time Monitoring System for CO Pollutant Concentration Using Fuzzy Logic on an Internet of Things (IoT) Platform and Telegram Around UNNES

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**Abstract.** The growth of the population and vehicles around the campus of Universitas Negeri Semarang (UNNES) has created new challenges related to traffic congestion and air quality. High traffic density can produce exhaust emissions, especially carbon monoxide (CO). CO is a toxic gas that comes from burning fossil fuels, such as those produced by motor vehicles. Long-term exposure to CO can cause serious health problems, including respiratory problems, cardiovascular disease, and even death. To address these issues, a real-time CO concentration monitoring system is required. However, the current CO concentration monitoring system has limitations in terms of accuracy and precision. The Fuzzy Logic (FL) method offers several advantages, including high accuracy and ease of comprehension. To implement this, research stages are necessary, including tool coding and data analysis using FL. The results of the research indicate that CO levels in each UNNES Faculty are approximately 3-20 ppm, with CO levels stabilising at 6 ppm. Therefore, the CO monitoring system using FL was successfully implemented.

## 1 Introduction

UNNES, a higher education institution located in Semarang, Central Java, is the center of academic, administrative, and community activities [1]. The growth in the number of people and vehicles around the campus creates new challenges related to traffic congestion and air

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quality. High traffic density can result in exhaust emissions, especially carbon monoxide (CO), which have a negative impact on human health and the environment [2]. CO is a toxic gas that comes from the combustion of fossil fuels, such as those produced by motor vehicles [3]. Long-term exposure to CO can cause serious health problems, including respiratory distress, cardiovascular disease, and can even lead to death [4]. Therefore, real-time monitoring of CO concentrations is a necessity to understand the level of exposure around UNNES and ensure the implementation of effective measures to address its impacts.

The use of the Internet of Things (IoT) in air quality monitoring has become an innovative and efficient solution. IoT-based systems enable real-time data collection, providing more accurate monitoring capabilities and rapid response to changing conditions [5]. By applying this technology, we can understand in more detail the patterns of CO concentrations, especially in the context of traffic jams.

Along with that, Telegram, as an increasingly popular and efficient instant communication platform, has become an important means of providing notification and information services. The integration of this platform in monitoring CO concentrations allows the dissemination of information directly to users or interested parties, such as students, staff, and the community around UNNES. It can increase awareness of the surrounding air conditions and provide the necessary information to take precautions.

The focus of this research is to provide a deeper understanding of the relationship between traffic congestion and CO concentration around UNNES. The data collected through the real-time monitoring system will provide valuable insights into the changing patterns of CO concentrations in various traffic conditions. The use of Telegram as a communication channel will facilitate the timely delivery of information to interested parties, support emission reduction policies, and raise awareness of the environmental impact of traffic. Through this research, it is hoped that a positive contribution can be made in the development of effective solutions to reduce the impact of traffic congestion on air quality around UNNES. In addition, this research can open up opportunities to develop similar systems in other urban areas, creating a cleaner and healthier environment for the community.

## 2 Method

This research was carried out in several stages, including preparing research tools, namely seven ESP32 microcontrollers, seven MQ-7 sensors, 28 Nylon Cross Screws, 28 Nylon Nut M3 hole 3mm hexagonal plastic drums, 28 Spacer plastic M3 Nylon Hex hexagonal plastics, four breadboards (2 x 3), seven black electronic boxes (18.5 cm x 11.5 cm) and research materials, namely glue. The next step is to make a lab permit letter in D9, the workshop room. Then create a C++ Program Code on the Arduino IDE Application. At this stage, the MQ-7 sensor optimization code and the MQ-7 sensor calibration code are obtained. This research first calibrates the sensor so that the results in the form of sensor output produce a linear and appropriate output. After the sensor is calibrated, the next stage is sensor optimization by testing the sensor at the lowest size and the highest size of the sensor's capabilities. In the sensor optimization stage, the sensor can work on the state and situation according to its environment and produce precise and accurate output. After that, assembling the device is done by making a simulation first through the Wokwi or Tinkercad application. This simulation aims so that when the device is assembled, it does not cause a short circuit and according to the program made. The next stage of sensor optimization is obtained by testing the sensor with a code that has been created at the lowest and highest states of the sensor's capabilities. Before the optimization stage is carried out, first calibrate the sensor. Sensor calibration is obtained by adjusting the calculation mathematically through a review of the sensor literature and environmental conditions during testing. And the last is data processing that is carried out using the Fuzzy Logic method by obtaining the value of the crisp set.

### 3 Result and Discussion

The development of a CO pollutant concentration monitoring system device using the MQ-7 sensor for the measurement of CO concentration is the principle of measuring CO using the MQ-7 sensor, namely the change in the resistance of the semiconductor material (SnO<sub>2</sub>) contained in the sensor when exposed to CO gas. The high heating mode is used to clean the sensor from the absorbed gas with the lowest value as a reference in determining the CO level. This process causes a change in the resistance of the semiconductor material. Resistance measurements are made by looking at the measured resistance change and converted into a voltage value read by the ESP32 and directly proportional to the concentration of CO gas in the air. This measurement requires calibration. Sensor calibration is performed according to the following mathematical formulation.

$$f(x) = a \cdot (x^b) \tag{1}$$

$$x = R_s / R_0 \tag{2}$$

#### Note

R<sub>s</sub> is a surface resistance to concentration sensitivity whose technical parameter value is 2 – 20k with a biomarker of 100 ppm. Surface resistance in MQ-7 sensor, shown in Figure 1. The R<sub>s</sub> coefficient value is 19.32 and R<sub>0</sub> is -0.64 with an R value of 1.0

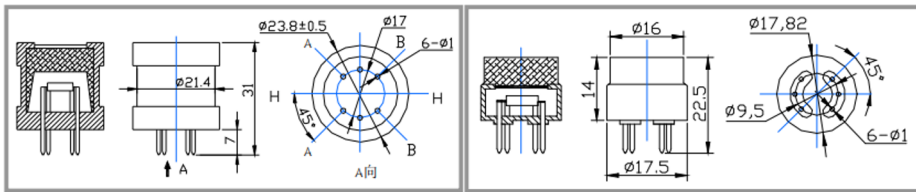


Figure 1. Structure and configuration of MQ-7 gas sensor

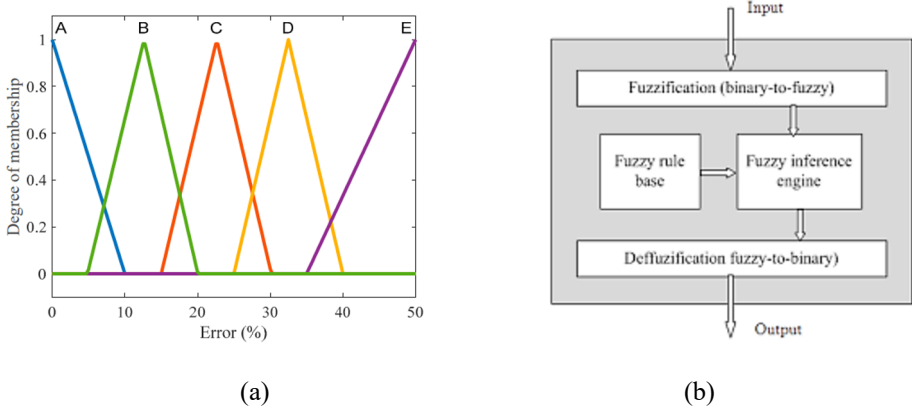
In Figure 1 it can be explained that the sensor is composed of an AL<sub>2</sub>O<sub>3</sub> microceramic tube, a sensitive layer of Tin Dioxide (SnO<sub>2</sub>), a measuring electrode and a heater are mounted into a crust made of plastic and stainless steel mesh. The heater provides the necessary working conditions for the work of sensitive components. The shrouded MQ-7 has 6 pins, 4 of which are used to pick up signals, and the other 2 are used to provide heating current.

#### 3.1 CO Measurement Using Fuzzy Logic

Fuzzy Logic (FL) go Fuzzy Logic (FL) goes through several stage to reach a complete solution with:

- 3.1. Fuzzification : includes defining the membership functions (MF) for the input variables to determine the degree of truth in each rule. The input contains one variable input from concertation CO with MQ-7 sensor shown in Figure 2 (a).
- 3.2. Inference: contains the fuzzy IF THEN rules. In the study, the FL rule were build bases on the experiment observations of concertation CO. The rule of FL solution as follows:
  - IF concentration CO = 0 – 10 ppm, THEN Normal
  - IF concentration CO = 8 – 20 ppm, THEN Middle

- IF concentration CO = 18 – 30 ppm, THEN High
  - IF concentration CO = 28 – 40 ppm, THEN Very High
  - IF concentration CO = 38 – 50 ppm, THEN Extreme
- 3.3. Defuzzification: the “centroid” that depends on the center of gravity is used to obtain the final output, which is error percentage of CO concentration



**Figure 2** Membership Function Of Input And Output In The Proposed FI System: (A) Mfs Of Co Concentration (B) FI Concept At Fis

Our suggested geoinformation service based on fuzzy logic (FL) has the capability to produce CO concentration values. This service utilizes advanced Program Codes to analyze geospatial data and predict CO levels with high accuracy. As shown in Table 1, the research indicates that the recorded CO concentration values vary significantly between different faculties at Universitas Negeri Semarang (UNNES). This variation can be attributed to several factors, including the differing levels of industrial activity, traffic density, and vegetation cover in the areas surrounding each faculty. Additionally, the proximity to major roads and urban centers may also influence the CO concentration levels. The data collected from this study provides valuable insights into the spatial distribution of air pollution within the university campus. By understanding these patterns, we can develop targeted strategies to mitigate CO pollution in the most affected areas. Furthermore, this research highlights the importance of continuous monitoring and analysis of air quality to ensure a healthy environment for students and staff. The implementation of our geoinformation service can serve as a model for other institutions aiming to address similar environmental challenges. Overall, the findings underscore the potential of geoinformation technologies in enhancing environmental management and public health.

**Table 1.** CO level with data collection in each faculty with a total of 7 faculties that have been taken CO data and Processing Data Analytics with FL Method

Faculty Data Insert	Min Output (ppm)	Max Output (ppm)	CO concertation with FL	Condition
Faculty of Medical	3	5	$3 \pm 0.3$ and $5 \pm 0.5$	Normal
Faculty of Education and Psychology	4	10	$4 \pm 0.4$ and $10 \pm 1$	Normal
Faculty of Technical	3	9	$3 \pm 0.3$ and $9 \pm 0.9$	Normal
Faculty of Sports Sciences	3	10	$3 \pm 0.3$ and $10 \pm 1$	Normal
Faculty of Social and Political Sciences and Faculty of Business and Economy	6	8	$6 \pm 0.6$ and $0.8 \pm 0.8$	Normal
Faculty of Law	6	14	$6 \pm 0.6$ and $14 \pm 0.4$	Middle
Faculty of Mathematics and Natural Sciences and Faculty of Language and Art	3	4	$3 \pm 0.3$ and $4 \pm 0.4$	Normal

The results showed that the FL geoinformation service based FL can measure CO concentration precisely and accurately with high accuracy and reliability values. In addition, the table shows that the Faculty of Law has a medium concentration value. This is because at the time of data collection, there were fewer trees in the Faculty of Law and the testing room was closed. However, the Faculty of Mathematics and Natural Sciences showed the lowest concentration value, which was 3 ppm and the highest 4 ppm. This is because in the Faculty of Mathematics and Natural Sciences there are many trees and testing is carried out in green open spaces.

At the research, development geoinformation service base FL, with Program Codes seemed to evaluate an accepted rate of accuracy and reliability of the CO concentration. Program Codes developed at the research can be seem in Program Code 1.

Program Code 1 Development Device Sensing CO concentration with FL In Arduino IDE Application
<pre> void setup() {   FuzzyInput *co = new FuzzyInput(1);   FuzzySet *low = new FuzzySet(0, 10, 10, 30);   co-&gt;addFuzzySet(low);   FuzzySet *medium = new FuzzySet(20, 40, 40, 60);   co-&gt;addFuzzySet(medium);   FuzzySet *high = new FuzzySet(50, 70, 70, 1023);   co-&gt;addFuzzySet(high);   fuzzy-&gt;addFuzzyInput(co);   FuzzyOutput *alert = new FuzzyOutput(1);   FuzzySet *safe = new FuzzySet(0, 0, 0, 45);   alert-&gt;addFuzzySet(safe); </pre>

```

FuzzySet *danger = new FuzzySet(30, 60, 60, 90);
alert->addFuzzySet(danger);
fuzzy->addFuzzyOutput(alert);
// fuzzy Rule
FuzzyRuleAntecedent *ifLowOrMedium = new FuzzyRuleAntecedent();
ifLowOrMedium->joinWithOR(low, medium);
FuzzyRuleConsequent *thenSafe = new FuzzyRuleConsequent();
thenSafe->addOutput(safe);
FuzzyRule *fRule1 = new FuzzyRule(1, ifLowOrMedium, thenSafe);
fuzzy->addFuzzyRule(fRule1);
FuzzyRuleAntecedent *ifHigh = new FuzzyRuleAntecedent();
ifHigh->joinSingle(high);
FuzzyRuleConsequent *thenDanger = new FuzzyRuleConsequent();
thenDanger->addOutput(danger);
FuzzyRule *fRule2 = new FuzzyRule(2, ifHigh, thenDanger);
fuzzy->addFuzzyRule(fRule2);
}
void loop() {
  int coLevel = mq7.getPPM();

  fuzzy->setInput(1, coLevel);

  fuzzy->fuzzify();

  float alertLevel = fuzzy->defuzzify(1);
  if (alertLevel == 0.0) {
    String message = "Error: Sensor not sensing";
    bot.sendMessage(CHAT_ID, message, "");
    delay(1000);
  } else {
    delay(1000);
  }
}
}

```

From Program Code 1 that has been created, it is then injected into the ESP32 microcontroller using the Arduino IDE application. This process involves compiling the code and uploading it to the ESP32, ensuring that the Program Code is correctly implemented on the hardware. After successfully injecting the code, the results are obtained as shown in Figure 3. These results demonstrate the functionality and performance of the Program Code when executed on the ESP32. The data collected from this experiment provides valuable insights into the efficiency and accuracy of the Program Code in real-world applications. Additionally, the use of the Arduino IDE simplifies the development process, making it accessible for researchers and developers.



## 3.2 Explanation of Research in Geography

Monitoring carbon monoxide (CO) concentrations in the neighborhood around Universitas Negeri Semarang (UNNES) provides important insights into the spatial and temporal variations of air pollutants. Using IoT technology and the Telegram platform, real-time data can be collected and analyzed to understand CO distribution across different locations and times. The analysis results show that the highest CO concentrations are found around the Faculty of Law, especially on Fridays around 11:30am. This peak is likely due to high motor vehicle activity, ahead of the lunch break when many people move around to have lunch or take a break. In contrast, the lowest CO concentration was detected at the Faculty of Mathematics and Natural Sciences (FMIPA) on Tuesday, ranging between 3-4 ppm. These low concentrations may be due to fewer motor vehicle activities in the area as well as the presence of more green areas. Other factors affecting the distribution of these pollutants include campus activity schedules, infrastructure layout, and environmental conditions such as wind and temperature. This information is critical to reducing exposure to air pollution, with better traffic management and infrastructure planning that supports cleaner air quality at UNNES.

## 4 Conclusion

This research successfully developed and implemented a real-time carbon monoxide (CO) concentration monitoring system using fuzzy logic on the Internet of Things (IoT) platform and integration with Telegram for information dissemination. Through the use of the ESP32 microcontroller and MQ-7 sensor, the system is able to measure CO concentrations with high accuracy and precision after going through the calibration and optimization stages of the sensor. Data collected from various faculties at Semarang State University (UNNES) showed significant variations in CO concentrations, ranging from 3 to 20 ppm, with stabilization at 6 ppm. This variation is influenced by factors such as traffic density, industrial activity, and vegetation cover around each faculty. The use of fuzzy logic allows the classification of CO concentration levels into several categories, which helps in the understanding and handling of air pollution conditions. The system also provides notifications directly to users through the Telegram platform, raising awareness and allowing for quick preventive measures. The results of this study not only contribute positively in reducing the negative impact of traffic congestion on air quality at UNNES, but also open up opportunities for the development of similar systems in other urban areas. Thus, this research provides innovative solutions for better environmental management and public health.

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