Air Quality Monitoring and Detection System in Vehicle Cabin Based on Internet of Things

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***Abstract*— clean air quality is necessary for breathing. Air quality in-vehicle cabin somehow unknowingly endanger the health of its passengers because of harmful substances or contaminated gaseous circulated inside. The purpose of this research is to build the prototype of an air quality monitoring and detection system, implemented in the vehicle cabin to raise awareness and help humans to monitor the air quality. The system is designed based on Prototyping methods with several stages of communication, quick plan, modelling quick design, construction of the prototype, and testing system functionalities. The components used for the system are the air quality sensor, temperature and humidity sensor, carbon-monoxide sensor, dust sensor, multiplexer, microcontroller, and IoT platforms. The prototype device is connected to IoT platforms Blynk Apps and Thing Speak. Blynk Apps and Things Speak which are set up on the smartphone could display the air quality measurement results graphically. From the testing and implementation, it is shown that the designed system could function according to the purpose of detection and monitoring.**

Keywords—detection system, Air Quality Index, sensor, Blynk, Thing Speak.

I. INTRODUCTION

A clean and healthy environment is one of the supporting factors for good air quality beneficial to health. Clean air quality is a basic need for humans and other living things. Humans need air that contains oxygen to survive. But there are other substances and particles in the air besides oxygen that can harm human health including carbon dioxide, nitrogen dioxide, carbon monoxide, formaldehyde, viruses, bacteria and other harmful substances that can be caused by air pollution [1].

Air pollution not only can occur indoor and outdoor but also inside vehicles. International Center for Technology Assessment (CTA) report that the level of pollution inside the cars are often much higher than pollution detected in the ambient air, at the roadside, and in other commonly used vehicles [2]. Air quality inside the car can be caused by the levels of accumulation of particulate matter (PM2.5) from large particles (such as pollen and dust) and nitrogen dioxide (NO_2) which is unhealthy to breathe or exert adverse health effects [3].

Air pollution can cause a decrease in air quality in the vehicle cabin. The level of pollutants inside cars is often higher because cars take emissions from surrounding vehicles and recirculate them [4, 5]. Car cabins that are exposed to pollution containing hazardous chemical compounds can trigger health problems such as respiratory, cardiovascular, cancer and several types of neuro-degenerative or brain diseases [6]. The vehicle cabin can be exposed to pollutants containing dust particles, ccarbon monoxide, nnitrogen ooxide and other harmful substances that enter the cabin when the doors and windows of the vehicle cabin are open [7]. In addition, cigarette smoke, air conditioner, air filters and high air temperatures can trigger chemical reactions in the materials in the cabin, resulting in hazardous substances such as benzene which can cause air pollution in the vehicle cabin [8, 9]. Pollutants found in car cabins [10] can be greater than 300 types of carbon-based gases mainly from Volatile Organic Compounds (VOC) [11] and combustive gaseous chemicals (NO_X, CO, etc.) and particles [12, 13]. Fig. 1 shows the negative factors which can influence indoor air quality in cars.

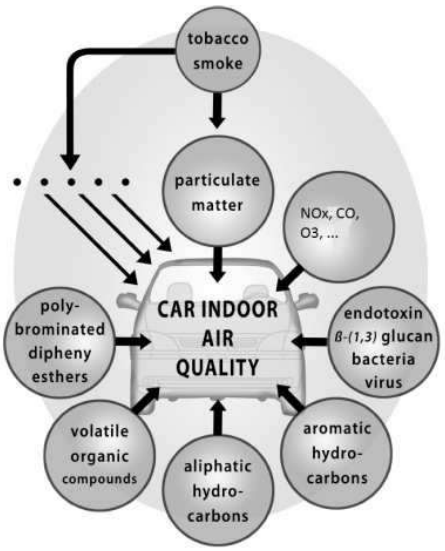

Fig. 1. Common pollutant types found in car cabins [14]

Along with the development of technology, the need and use of technology today reach various fields of human life. Technology makes it easier for humans to communicate, share information and even control human activities every day. Internet of Things (IoT) is a technology that continues to develop today. IoT refers to an interrelated system with computing devices, mechanical and digital machines, objects, animals or people which can transfer data through the network without requiring human to human or human to computer interaction [15, 16]. IoT represents the design of powerful technology which allows multiple devices connected at any time and location without intervention [17, 18]. With the use of the IoT, humans can control, monitor and integrate various sophisticated equipment and devices easily and effectively [19].

IoT concepts and technology are used in this research as an alternative solution in raising the awareness and importance of air quality by creating a system for monitoring

and detecting air quality in the vehicle cabin. By utilizing the IoT, vehicle users can obtain information through a monitoring and detection system for air quality in the vehicle cabin and can access the information generated from this system via a smartphone connected to the internet.

II. Literature

A. System

The system is a combination of components that are interrelated and connected between one component with other components which aim to solve a problem and achieve a goal. The systems approach can be divided into two, namely the system approach in procedures and the system approach in elements or components. The procedural system is a systems approach that consists of several procedures or steps which contain a series of interrelated activities to achieve certain goals. The system approach in elements or components is a system consisting of a set of components or elements that interact with each other to achieve certain goals [20]. The classification and certain characteristics of a system [21] are described as follows:

1. *System Components*: The system is a series of interacting components where a series of system components consists of several parts or subsystems which form a unified system.
2. *System Boundary*: The system boundary is the scope that limits the system to other systems or systems with the outside environment where the system has its scope that cannot be separated.
3. *External Scope of the System*: The environment outside the system is related to all things which come from outside the boundaries of the system that can affect the way the system works, whether it is beneficial or detrimental. The environment outside the system which benefits must always be maintained, while the environment outside the system which detrimental must be controlled so that it does not interfere with the workings of the system itself.
4. *System Link*: A system link is a liaison of one subsystem with other subsystems so that the resources of a subsystem are utilized by other interrelated subsystems.
5. *System Input*: System input is the energy that is entered into the system in the form of maintenance inputs that support the operation of the system and input signals that produce output or information.
6. *System Output*: The output generated by the system can be utilized by other subsystems.
7. *Processing System*: A system can perform data processing by converting input into output.
8. *Goals*: Each system has a goal to be achieved. A system can be categorized as successful if the goals and objectives are in line with the planned objectives.

B. Detection

According to the Cambridge dictionary, detection is the fact of noticing or discovering something [22]. The detection system can be concluded as a technique to identify to solve a problem. In this research, the detection is a process of examining the condition of air quality in-vehicle cabins through the use of sensors.

C. Monitoring

Monitoring is a process of collecting information and analyzing an ongoing and systematic program or activity. The monitoring system is a monitoring process with certain steps carried out to determine the actual performance process or activity match the specified standard performance. Monitoring is carried out by making measurements against time which indicate movement towards the goal or away from the specified standard performance. Monitoring aims to evaluate a condition or activity to maintain the ongoing performance of an object [23].

D. Internet of Things

Internet of Things is a concept of the interaction of two or more identifiable objects that are connected and controlled through the internet network. The purpose of the IoT is to allow everything to communicate with anything, anyone, anywhere and anytime without any limitations and obstacles [19].

E. Air Quality

Air quality refers to the Air Quality Index (AQI) which is indicated the concentration of pollution in the air [24, 25]. Less pollutant in the air means good air quality, while more pollutant means a poor air quality.

F. Related Research

The research [26] discussed automatic control systems for air pollution detection and rash driving prevention in vehicles using components such as ARM-7 microcontroller, CO sensor, MQ2 sensor, alcohol sensors, GSM module and LCD. Other research [27] a novel approach to implement self-controlled air pollution detection in vehicles using smoke sensors were implemented using ARM-7 microcontroller, MQ2 Sensor, GSM module, and LCD. Research [28] automated control system for air pollution detection in vehicles using components PIC microcontroller, LM35 sensor, CO sensor, GSM and LCD. Research [29] automated system for air pollution detection and control in vehicles arm microcontroller, CO sensor, NO_x sensor, SO_x sensor, temperature sensor, GSM and sound alarm. Research [30] real-time in-vehicle air quality monitoring system using machine learning prediction algorithm with components such as CO_2, particulate matter, vehicle speed, temperature, and humidity connected to cloud database. Those research, specifically discuss air quality in the vehicle with its approach and different components.

Previously in [31, 32], the researcher had designed and built an air quality monitoring system implemented in an indoor area using air quality sensors. In this research, the development has been made especially for air quality monitoring system in the vehicle cabin, which added sensors to detect air quality, temperature, humidity, carbon monoxide and fine particles such as dust. In this research, the scope is to design a real-time system that can monitor and detect the air quality in-vehicle cabin and inform the user. The system depends on a reliable internet connection. The prototype and user smartphone are set up with IoT platforms are in a nearby coverage area.

G. Research Method

Prototyping Model [33] is a development method with five stages that started with communication that aims to collect the

requirements needed in the development of this system. The next stage is a quick plan aimed at identifying all components to be developed using the Unified Modeling Language (UML) and a modeling quick design aimed to design the system. The next stage is the construction of a prototype that aims to combine hardware components and programming code. After merging hardware and programming components, the system is run and tested for its functionality. Researchers use this method because each process can be done repeatedly until achieving the appropriate results and matching the user needs.

Some of the variables that were observed in this study were air quality, temperature, humidity, carbon monoxide gas and fine particles in the vehicle cabin. Research instruments related to the types of data and data collection techniques as well as the system development environment are used in this study. For data collection techniques, researchers conducted interviews and literature studies based on theoretical references.

III. Results

A. System Design

Fig. 2 shows the design of the air quality monitoring and detection system in the vehicle cabin which describes the flow processes and interactions between components.

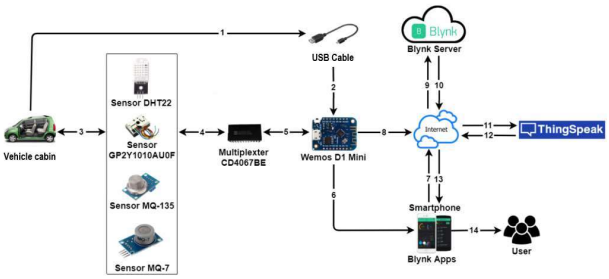

Fig. 2. System Design of Air Quality Monitoring and Detection System in Vehicle Cabin Based on Internet of Things

Fig. 2 is explained as follows.

1. The vehicle engine through the 12V DC car cigarette lighter socket functions as a power supply to the Wemos D1 Mini microcontroller when the vehicle machine is turned on.
2. The USB cable connects the Wemos D1 Mini microcontroller to the power supply.
3. After Wemos D1 Mini is connected to the power supply, sensor modules DHT22, MQ135, MQ7, sensor GP2Y1010AU0F can perform detection of air quality in the vehicle cabin.
4. The multiplexer switch inputs from the sensor module MQ135, the MQ7, the GP2Y1010AU0F sensor and DHT22 using the logic circuit of the CD4067BE multiplexer into an output line.
5. After the multiplexer switches the input line to an output line, the detection data is forwarded to the Wemos D1 Mini.
6. Wemos D1 Mini is connected to a hotspot internet provided by the smartphone so that it can communicate and transmit data to Blynk Apps and Thing Speak.
7. Smartphones must have an internet connection so that data could be sent to the cloud.
8. After the Wemos D1 Mini is connected to the internet, it is processed and sent the monitoring and detection results.
9. Data that has been processed by the Wemos D1 Mini microcontroller is then sent to the Blynk server.
10. Blynk Server processed data sent by the Wemos D1 Mini and forward the sensor detection data to Blynk Apps.
11. The Wemos D1 Mini also sent sensor detection data to Thing Speak.
12. Thing Speak processed the input sent by Wemos D1 Mini and visualize the data in graphical form.
13. Data on the Blynk Server is pushed to Blynk Apps on the user's smartphone and data from Thing Speak can be accessed through thingspeak.com via a browser on the user's smartphone or computer.
14. Users can find out and check air quality on Blynk Apps and Think Speak to get information or notifications about air quality in the vehicle cabin.

B. System Analysis

Fig. 3 explain the analysis of the air quality monitoring and detection system using the use case diagram in UML. The system has entities that connected each other. The Wemos D1 Mini processed the data generated from sensors and sent to the IoT platform Blynk Apps and Thing speak. Users can access air quality information through Blynk Apps and Thing speak.

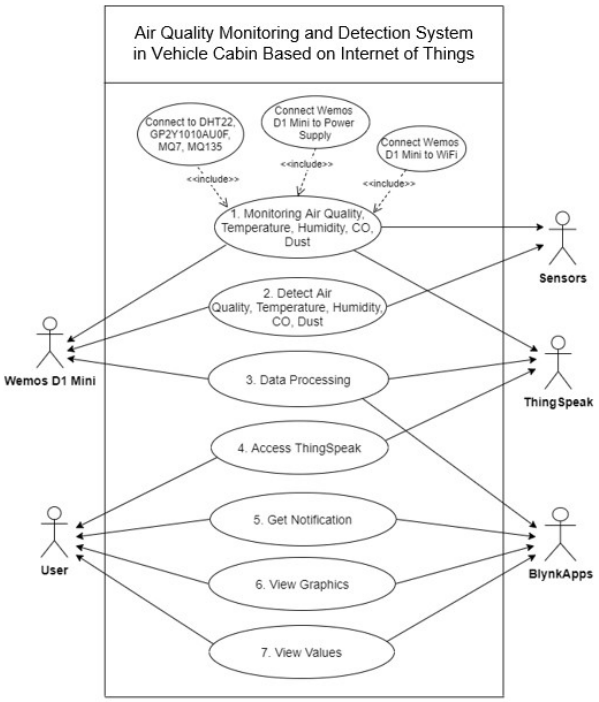

Fig. 3. Use Case Diagram

C. Prototype Design and Implementation

Fig. 4 show the prototype schematic circuit with its interrelated electronic components. The components used in the system are the Wemos D1 Mini board microcontroller to process data from the sensor, DHT22 temperature and humidity sensor, GP2Y1010AU0F dust sensor, MQ135 air quality sensor, MQ7 carbon monoxide sensor, multiplexer CD4067BE as a logic gate for input and output of sensor data

to the Wemos D1 Mini, resistors, capacitors, and a breadboard. The voltage for the sensors connected to the Wemos D1 Mini Vcc pin is set to 3.3 volts. The system circuit schematic in Fig. 4 was created using Fritzing software.

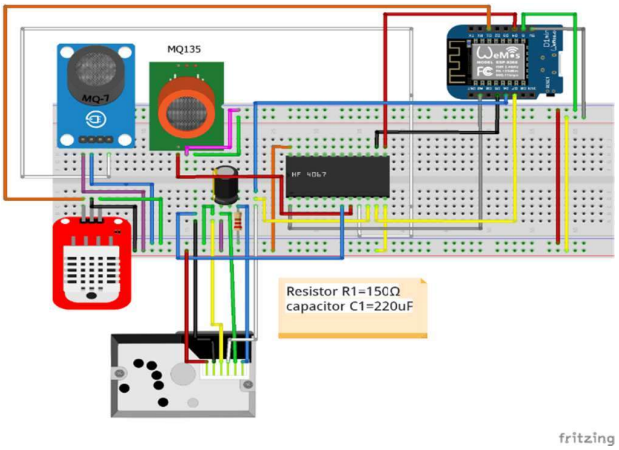

Fig. 4. Design prototype device for air quality monitoring and detection system

Fig. 5 show the prototype device placed in the vehicle cabin dashboard. The device is connected with a USB cable which is plugged into a cigarette lighter with 12V DC power to provide power. The code program was injected into the Wemos D1 microcontroller using Arduino IDE. The program is controlling the whole process of monitoring and detecting air quality.

Fig. 5. Implementation of the prototype device in vehicle cabin dashboard

D. *Blynk Apss Implementation*

IoT platform Blynk Apps serves to display the value of monitoring and detection results from the prototype. Fig. 6 show the Blynk Apps implementation display on the smartphone. Vehicle users can access information of sensor detection results, through Blynk Apps that have been installed and set up on the user's smartphone with an internet connection activated. The value of each sensor displayed through Blynk Apps shows that the temperature is 29.400 Celcius, 65.3 % humidity, CO value of 42.823 ppm, air quality in 29.749 particulate matter, and dust in 0.007 ppm. The measurement results of air quality at the time of testing shows that overall air quality inside the vehicle cabin is at a good level, which means that the air quality is good with no health impacts.

Fig. 6. Blynk Apps Implementation

E. *ThingSpeak Implementation*

IoT Platform ThingSpeak displayed the monitoring of air quality, temperature, humidity, carbon monoxide and fine particles in the air through the graphical form. Fig. 7 to Fig. 10 shows the data detection from each sensor and recorded by the Thing Speak.

The data recorded by ThingSpeak are generated in real-time and store in the cloud. Vehicle users can monitor the air quality data via the thingspeak.com website which can be accessed through a smartphone or a computer. This data can be analyzed in future which is beyond the scope of this research.

Fig. 7. ThingSpeak display the temperature detection

Fig. 8. ThingSpeak display the humidity detection

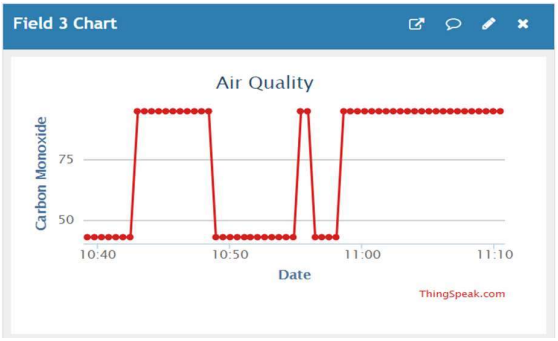

Fig. 9. ThingSpeak display the carbon monoxide detection

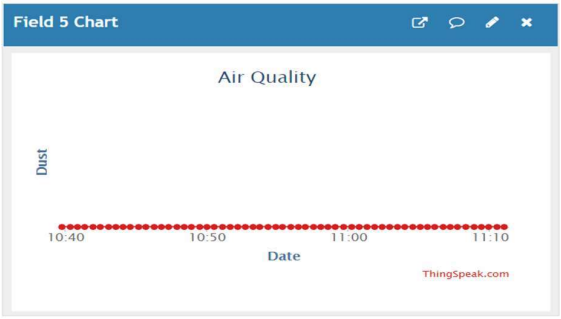

Fig. 10. ThingSpeak display the dust detection

F. Testing

Based on the final tests shown on TABLE I. the system running according to the purpose.

TABLE I. FINAL TESTING OF THE SYSTEM

Testing Types	Condition	Results
System functional testing	Components are well connected and integrated	Succeed
Tests to display air quality values in Blynk	The detection result value can be displayed on Blynk Apps	Succeed
Testing to show air quality notifications in Blynk Apps	The notification is successfully displayed when the sensor detects beyond the sensor threshold	Succeed
Testing display on ThingSpeak when the vehicle engine is started	The value of the detection results can be monitored via the graph on ThingSpeak	Succeed
Testing the display on ThingSpeak while driving the vehicle		

IV. Conclusion

The research has several conclusions. The air quality monitoring and detection system in the vehicle cabin consist of hardware and software components. The air quality prototype mainly consists of sensors and microcontrollers connected through the Blynk Apps and ThingSpeak as IoT software. The prototype is placed inside the vehicle cabin can sense and measure the air quality stimulus and send the results through the Blynk Apps and Thingspeak which are set up on the user smartphone. The functionalities of the system were tested and showed that the monitoring and detection of air quality can be performed according to the research purpose.

V. Future Research and Discussion

Future research of the system related to the functionalities testing of the system is to compare the results of air quality from the designated prototype with the other conventional tools to find any similarities or differences. The prototype could be redesigned using a printed circuit board (PCB) and improved by adding sensors to optimize air quality detection. In terms of the data recorded in ThingSpeak, it could be further analyzed to get the average value of air quality in a periodic time.

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