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Development of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

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Abstract

Efforts to reduce damages from micro dust and harmful gases in life have been led by national or local governments, and information on air quality has been provided along with real-time weather forecast through TV and internet. It is not enough to provide information on the individual indoor space consumed. So in this paper, we propose a IoT-based Real-Time Air Quality Sensing Board Corresponding Fine Particle for Air Quality Management in Buildings. Proposed board is easy to install and can be placed in the right place. In the proposed board, the air quality (level of pollution level) in the indoor space (inside the building) is easy and it is possible to recognize the changed indoor air pollution situation and provide countermeasures. According to the advantages of proposed system, it is possible to provide useful information by linking information about the overall indoor space where at least one representative point is located. In this paper, we compare the performance of the proposed board with the existing air quality measurement equipment.

Keywords: *Air Quality, Real-Time, IoT, Complex Sensor Board, Air Management*

1. Introduction

Fine dust is atmospheric pollutants including sulfur dioxide, nitrogen oxides, lead, ozone, and carbon monoxide, which are generated from automobiles and factories and float in the air for a long time. Fine dust having a particle size of 10 μm or less is called PM 10, PM 2.5 which having a particle size of 2.5 μm is called to as "ultrafine dust". The results of this study show that the times required for the fine dust to settle within 8 feet (about 2.5 m) of the atmosphere are 13 minutes for 10μm and 19 hours for 1 μm [1].

Fine dusts are naturally occurring dusts such as dirt, seawater salt, and pollen from plants or generated when burning fossil fuels such as coal and oil in boilers and power generation facilities, automobile exhaust gas. And it is also caused by anthropogenic causes such as powdery raw materials in the factory, powder components in the processing of subsidiary materials, and smoke from incinerators. As for the risk of fine dust, the World Health Organization (WHO) classifies it as Group 1, and it induces or exacerbates

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respiratory disease, cardiovascular disease, asthma and the like in the human body, and sulfur dioxide (SO_2) Or nitrogen dioxide (NO_2) lower the acid rain to acidify the soil and water, destroying nature and ecosystems [2].

In Korea, the environment has been continuously deteriorated due to rapid industrialization and urbanization. Especially, the environmental pollution of large cities and industrial complexes is serious. We are aware of the harmfulness of air pollutants generated and propagated here through various research data and reports, but we are living in anxiety without actively coping with them. And also Most of the researches have been done on the related solutions, but most of them have been based on the measurements of indoor space in indoor monitoring [3][4].

So in this paper, we proposed IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings for a new air-conditioning system using air-condition sensors and IoT-based microcontroller (ATmega328p). The proposed board can easily install in building and monitor the air quality (level of pollution) in the indoor space. By using monitoring data, it can recognize the changed indoor air pollution situation and prepare countermeasures accordingly. Furthermore, it can provide useful information by linking information about the overall indoor space.

The order of this paper is as follows. In chapter 1, we described about introduction of this paper. And chapter 2, we described about IoT-based simple sensor board design. In Chapter 3, actual sensor board was implemented to confirm operation and review in actual building. Finally, in Chapter 4, we concluded about this paper.

2. The Design of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

2.1 The Used Microcontroller

The microcontroller uses Atmel's microcontroller, which provides various things such as the connection of the Internet(IoT) and open-source based Integrated Development Environment (IDE) that helps programming. That microcontroller will be worked acquire the data from air related sensor, and then show this data during transmit to the integrated monitoring system. The Reason why we accepted Atmel's microcontroller is it can support users to use the same program development environment as Arduino which an open source microcontroller.

2.2 The Used IoT Module

The characteristic of the air quality integrated sensor is not a compact structure installed in a small space. It is installed intermittently at a certain distance such as a source of contamination, a dense place of a person, and has an environmental characteristic to be installed in a space where walls and obstacles exist [5]. Considering such sensor installation location and monitoring characteristics, it is useful to utilize Zigbee or LoRa communication, but we accepted the Wi-Fi Module which can be easily purchased and used in daily life.

2.3 The Used Sensors for Monitor Air Quality

To measure complex air quality in buildings using IoT in real time, temperature and humidity sensor

(ETH-01D), carbon monoxide sensor (GEST11-P110), volatile organic compound sensor (GSBT11-P110), carbon dioxide sensor (MH-Z19), differential pressure sensor (53A Series), fine dust sensor (PMS7003), A total of six sensors were selected and the building air quality was measured through the combined operation of each sensor.

3. Implementation and review of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings.

In this chapter, we implemented the proposed system that IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings. And compared the results with those of commercial products.

3.1 Implementation of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

Fig. 1 shows the architecture of IoT based Real-Time complex sensor board for managing air quality in buildings. The configuration of the integrated sensor board for minimizing the interference of the six sensors installed on the sensor board and making it as small as possible.

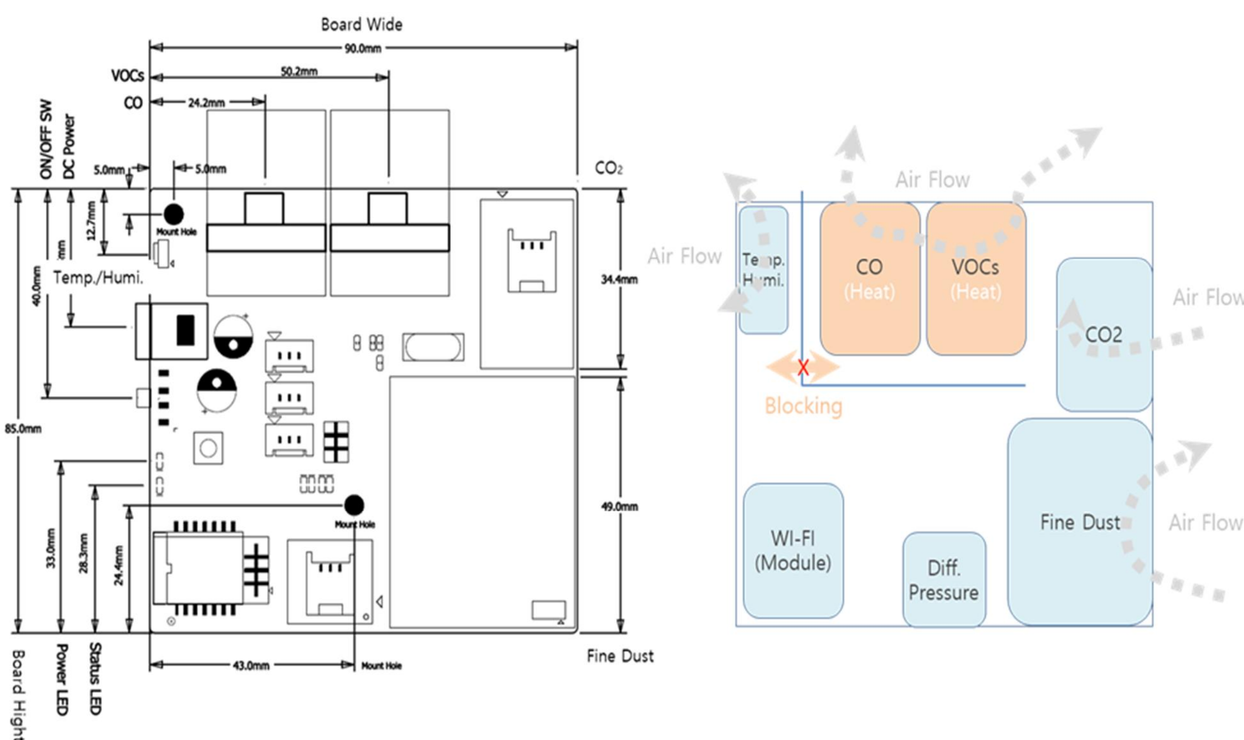

Figure 1. The schematic of IoT-based Real-Time complex air quality sensing board

Table 1 summarizes the operating voltages of the sensors applied to the integrated sensor board and the types of signal output to be transmitted to the microcontroller. The calculation arithmetic expression and the interface protocol provided in the respective data sheets of each sensor are used to input IoT based real-time air quality measurement sensor board was designed by considering the measurement value from the signal or by receiving the measured value through communication.

Table 1. Complex air quality measurement sensors and operating ranges

Sensor Item	Model	Operating Voltage (DC)	Signal Output (Interface)
Temp./Humidity	*ETH-01D*	1.8 ~ 5.5V	Digital (I2C)
CO	*GSET11-P110*	5V	Analog (0.5 ~ 4V)
VOCs	*GSBT11-P110*	5V	Analog (0 ~ 5V)
CO2	*MH-Z19*	5V	Digital (PWM)
Difference Pressure	*53A Series*	4.5 ~ 5.5V	Analog (0.5 ~ 4.5V)
Fine Dust	*PMS7003*	5V	Digital (UART)

We Selected the sensors that can operate at 5V, which is easy to supply power from the board, and send data based on various signal processing/communication methods such as analog, I2C, PWM and UART. It is designed to be supported.

3.2 Hardware Implementation and Packaging of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

Based on the previously proposed IoT hardware configuration proposal, a board that assembles microcontroller, air quality sensor and communication device into one board was assembled. In order to protect the sensor and install the information display device, And the indoor air quality integrated sensor device as shown in Fig 2.

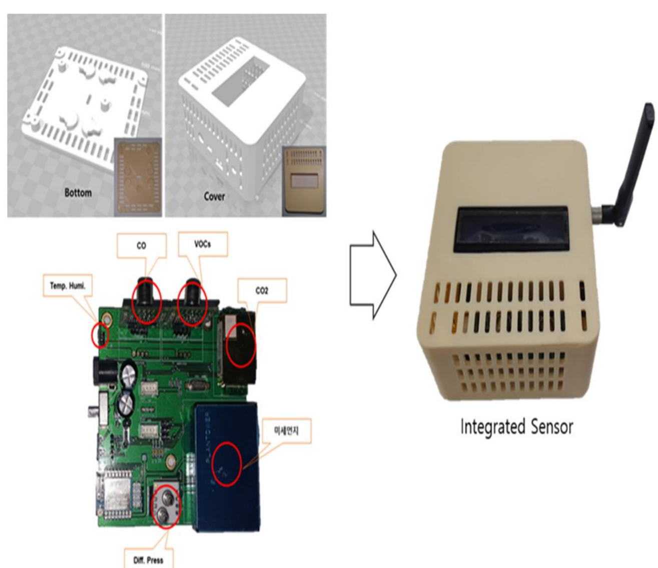

Figure 2. The packaging result of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

3.3 Software Implementation of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

We implemented the SW that was designed on the previously designed IoT-based real-time air quality sensor boar. The sensor board was made using Arduino's microcontroller (ATmega328p). I/O and communication ports used in the setup function are defined starting from the definition of external/internal variables for use of the devices connected to the microcontroller and must be repeatedly performed in the loop function The sensor value calculation function and the communication memory update function. Fig. 3 shows a flow chart of the IoT-based real-time air quality sensor board operating SW that has been implemented as described above. The software collects data of various sensors attached to the sensor board and displays it.

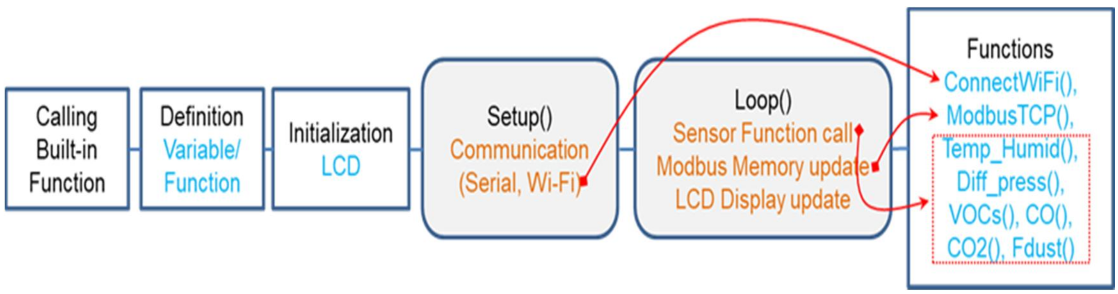

Figure 3. The Flowchart of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

The software includes a program for collecting data of various sensors attached to the sensor board and displaying the data itself, as well as a general protocol support for transferring the collected data to the monitoring server. We tried to apply the modbus protocol supported by Arduino, but the modular parse protocol, which is simplified to support only some functions of the modbus function, is difficult to accommodate in the microcontroller (ATmega328p) to which the function size is applied. The sensor measurement values collected by the microcontroller of the sensor board were written to configure the Modbus map in the monitoring server so that the data can be sent out immediately when a data request using the Modbus protocol is received. Table 2 shows the contents of the Modbus register provided by the sensor.

Table 2. Sensor board memory map

Register	Address(16bit)	Value
30001	*0x000*	Temperature
30002	*0x001*	Humidity
30003	*0x002*	Difference Pressure
30004	*0x003*	Spare
30005	*0x004*	VOCs (Formaldehyde)
30006	*0x005*	VOCs (Toluene)
30007	*0x006*	CO
30008	*0x007*	CO2
30009	*0x008*	Spare
30010	*0x009*	PM2.5
30011	*0x00A*	PM10

3.4 Test and Review of IoT based Real-Time Complex Sensor Board for Managing Air Quality in Buildings

In this section, based on the actual IoT-based real-time complex air quality measurement sensor board, we constructed an environment for measuring the response of harmful substances including the fine dust of the integrated sensor and the reliability of collected data. Figure 4 through Figure 9 show the results of comparing the measured values with the standard measuring device.

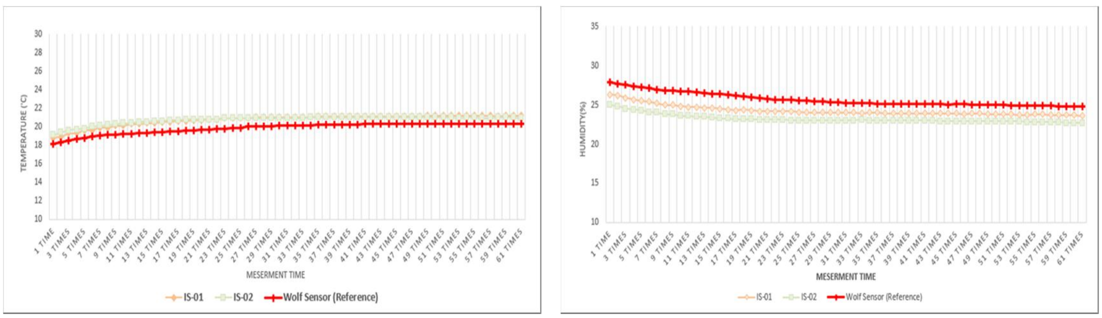

Figure 4. The Result Graphs with proposed board and commercial device about Temperature and Humidity

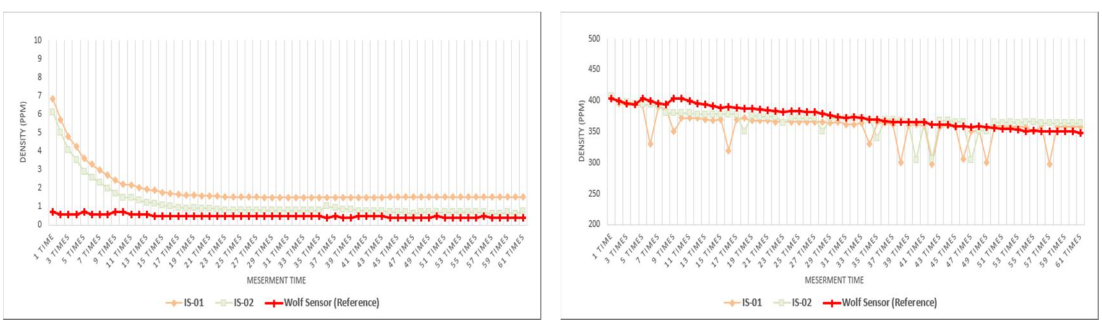

Figure 5. The Result Graphs with proposed board and commercial device about carbon monoxide and carbon dioxide

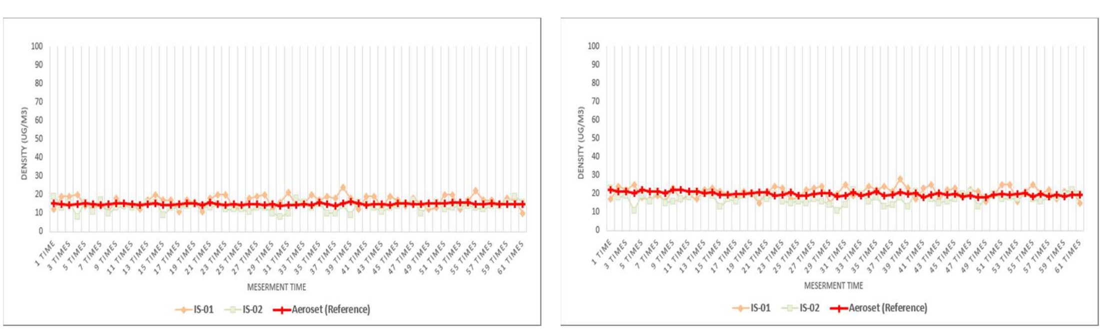

Figure 6. The Result Graphs with proposed board and commercial device about PM2.5 and PM10

As a result of the comparison about proposed board and commercial device, the temperature and humidity were slightly different from those of the standard device, but it could be improved through the correction process of the measured values by applying the error correction algorithm. In the case of carbon monoxide, Over the years, the measurement values of the standard equipment have changed approximately.

In the case of carbon dioxide, an intermittent measurement error occurred, but it was confirmed that it was close to the standard device in the whole flow.

In case of fine dust(PM 2.5, 10), it is confirmed that the middle value is approximate to the standard device but it is necessary to apply the error correction algorithm to the intermittent vertical error.

4. Conclusion

Recently, the frequency of reception of safety guiding letters is gradually increasing due to the deterioration of air quality. Accordingly, there are received outdoor driving instructions such as wearing a mask and driving a car, etc. However, there is no method for recognizing fine dust existing in the outdoors, harmful substances present in the room, and the situation where fine dust and harmful substances are generated and diffused in the room.

In this paper, an integrated sensor based on IoT is designed and implemented to easily measure and inform the distribution of fine dust and harmful substances that are generated in indoor and indoor air of fine dust and harmful materials. We compared improvements with measuring instruments and found improvement. It was confirmed that data can be obtained for indoor air quality management by using integrated sensor implemented by combination of general purpose microcontroller and sensors without using expensive measuring equipment. In addition, it is designed to enable real-time communication with any monitoring facility by applying MODBUS, a standard universal communication protocol of the industry.

The indoor air quality integrated sensor implemented in this paper can drastically reduce the budget for the construction of the existing air quality monitoring system composed of the expensive air quality measuring equipment and it is possible to reduce the air quality of the public places such as subways, it provides a foundation for easy access to useful information on a small budget.

The integrated sensor implemented in this study introduces a method of collecting and transmitting a large number of air quality signals to improve the indoor environment in place of an expensive sensor by combining a universal IoT component, and it can be used in a monitoring system.

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