Manufacturing A Low-cost Telegram and Optical Character Recognition-based Indoor Air Quality Monitoring Data Logger

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***Abstract*— Urban air is frequently contaminated with CO, CO2, VOC, HCHO, PM 2.5, and PM 10. Rural regions are at a lower risk than those near roads and industrial areas that produce emissions. Air pollutants negatively affect its inhabitants' health, particularly the respiratory system. Most people will spend more time indoors, requiring a method for monitoring indoor air quality (IAQ). Urban communities need IAQ monitoring instruments as an early warning system for their health. This research seeks to produce inexpensive IAQ that can be utilized by all levels of society, particularly urban communities. This research utilizes a qualitative, design-thinking-based methodology. The research diverged from Empatize, which asserts that urban communities require a method for determining the local air quality. Moreover, it is determined at the define stage that IAQ monitoring, which includes a data log feature, is still comparatively expensive, so a solution is developed at the ideate stage. Creating a prototype is the next step in realizing the specified solution. In this investigation, they decided to use IAQ monitoring, which is relatively inexpensive but lacks log data storage. The author uses the ESP32-cam microcontroller to capture the screen display device, and the resulting image is sent to a telegram and processed with optical character recognition (OCR) to generate a data log. The results of prototype testing are utilized for prototype development.**

Keywords—air pollutan, health, IAQ, respiratory system, urban

I. INTRODUCTION

Environmental air quality has an impact on indoor air quality (IAQ)[1]. Humans spend approximately 10 hours a day working outside their houses. It implies that the remaining fourteen hours will be spent at home. According to The National Human Activity Pattern Survey (NHAPS) in [2] survey, 86.9% of people spent their time indoors. It means that even people who work will spend their time indoors. IAQ thus plays a significant part in preserving people's health [3]. A clean environment plays an essential role in preserving the well-being and comfort of its inhabitants [4], [5]. Due to a lack of understanding of the significance of clean IAQ, recent decades have seen a drop in air quality due to rising population density, urbanization, and energy efficiency [6], [7]. Distributing air exchange between the interior and outside of the building is another benefit of using ventilation systems in buildings. Building ventilation systems can reduce the risk of indoor air pollution, which can harm human health, by performing better ventilation systems [8], [9].

The air quality in urban areas, particularly areas surrounding main roads, is subpar. It results from the emission of numerous substances and particles by motor vehicles [10], [11]. Burning transportation fuels results in the production of carbon monoxide (CO) and carbon dioxide (CO2) gases, which are air pollutants [12]–[14]. Formaldehyde (HCHO), a known carcinogen in outdoor air, is another gas that motor vehicles produce. Among the 187 hazardous air pollutants (HAPs) identified by the U.S. Environmental Protection Agency (EPA), it is the most important carcinogen in outdoor air [13], [15]. Volatile organic compounds (VOCs) are also air pollutants that are chemical compounds found in numerous products that easily vaporize and enter the environment under normal circumstances. Food extraction, using fertilizers, and applying pesticides are examples of residential and industrial operations that produce VOCs [16]. Particulate matter (PM) is a mixture of solid particles and liquid molecules in the surrounding environment. PM10 are inhalable particles with diameters generally less than 10 micrometers; PM2.5 are fine particles with diameters generally less than 2.5 micrometers. PM10 and PM2.5 are components of particle pollution [17]–[19]. Exposure to these gases can have short- and long-term effects on human health, particularly the risk of respiratory diseases.

These gases are invisible to the naked eye but can be measured using a monitoring device [12], [20], [21]. Several monitoring instruments sold on the market are prohibitively expensive and out of reach for most people, particularly those in the lower middle class. The higher the price, the more extensive the reading of the gas particles. In addition, these instruments with log data will be relatively costly. This log data is essential because it can be used to evaluate a situation. It must be meticulously monitored for days, weeks, or even months. As a result, low-cost monitoring research must be conducted so that the findings can be applied to all levels of society [22].

Several previous studies have been carried out, such as the effects of air pollutants on human health [3]. Research related to air pollutants such as CO and CO2 [12]–[14], HCHO [13], [15], VOC [16], PM 2.5, and PM 10 [17]–[19] have also been studied, and it is known that the cause comes from vehicle motor emissions and industrial. Gases that cannot be seen with the naked eye will be detected using tools made using technology, such as research conducted by Alabdullah et al [20], Dari et al [12], and Gunawan et al [21]. It is necessary to conduct research that uses affordable devices, as Kumar Sai [22] did, for the device to be accessible to all groups. IAQ monitoring research that implements low-cost methods with maximum results is a novelty in this writing.

Every resident should know the air quality in their immediate surroundings, whether at home or in the office. It is critical to know the air quality in the room, the main environment where people spend their time, using a device that can monitor IAQ. This device may also identify local air contaminants for the last 24 hours by employing a data log. Using this device, users may determine when the room has good air quality on average and when air pollution appears. Users do not obtain data logger features while using IAQ monitoring solutions that are widely available at affordable prices. Data logger-equipped tools are relatively pricey. As a result, this research has an urgency to develop a prototype with a relatively low cost and has data logger facilities so that it can be used to analyze IAQ in a room.

This study aims to manufacture a device on how to make low-cost IAQ monitoring. The author hopes this paper will contribute to the community so that they consciously apply this tool to monitor the surrounding air as an early warning of air quality. By knowing the condition of the room quantitatively, users can make decisions or create a solution to provide a ventilation system in the room, as Pramono et al. did [23].

II. Methodology

The method used is qualitative with a design thinking approach. Design thinking stages are divided into five stages: empathize, define, ideate, prototype, and test. At the initial stage, empathize, the author reads a phenomenon that monitoring air quality is very important for everyone. IAQ monitoring can function as an early warning for its users' health if conditions do not comply with the specified standards. The next stage in design thinking is Define. It determines the problem that IAQ monitoring devices, especially those with data logs, are relatively expensive and only affordable to some Indonesians. Therefore, a solution—low-cost IAQ monitoring—is required so that IAQ monitoring devices are accessible to all users. This stage in design thinking is called ideate. Still at the ideate stage, the author analyzes the price of IAQ monitoring without log data which is relatively cheaper than using log data. To find a middle ground is to create a tool to capture numbers on IAQ monitoring without data logs and process the image into a text using Optical character recognition (OCR).

After the solution is solved, move on to the next stage, namely the prototype. The author creates a device to capture the IAQ monitoring screen at this stage. The author uses an ESP32-cam, a microcontroller equipped with a camera. Image results are sent via the Telegram application every 5 seconds. At this point, the author has moved on to the testing phase, which entails figuring out the ideal distance for taking photos so that OCR software can read them. After getting the appropriate distance, the next step is to return to the prototype by making an IAQ monitoring holder and a holder for the ESP32-cam using a 3D printer. The next step is to place the IAQ and ESP32-cam on the holder that has been made and do the testing. This step is continuous until it gets the desired result. Step-by-step design thinking can be seen in Fig. 1.

Fig. 1. *Step-by-step of methodology reasearch*

III. Result and Discussion

In this study, the author used IAQ monitoring to measure CO, CO2, TVOC, HCHO, PM 2.5, and PM 10 gas levels. This device can only display air quality conditions without being equipped with a data log. The price of this device is around 38 USD, much cheaper than those equipped with data logs, which are around 540 USD or more. The purpose of choosing a device that is cheaper and not equipped with a data log is so that it can be purchased and can monitor room conditions. If a more in-depth observation of a room is needed, it is necessary to capture it to obtain quantitative data. By sending data for 24 hours, the research results on a room's air quality can be achieved at an affordable price.

A. Phase one manufactures a prototype capturing device that is connected to Telegram

The initial stage of this prototype is to make a device that can take pictures of objects. The author chose to use an ESP32-cam as a microcontroller. The author sets the device can take a picture every 5 seconds and send it to Telegram. For its manufacture, connect the receiver (RX) on the ESP32-cam board connect to the USB TTL transmitter (TX). Meanwhile, the TX on the ESP32-cam connects to RX USB TTL. The ground on the ESP32-cam connects to USB TTL ground, and so does the power on the ESP32-cam connect to 5V USB TTL. To strengthen the signal on the ESP32-cam, it needs to add an external antenna so that the process of sending data to Telegram via WiFi can be faster. Connection details on the ESP 32 cam can be seen in Fig. 2.

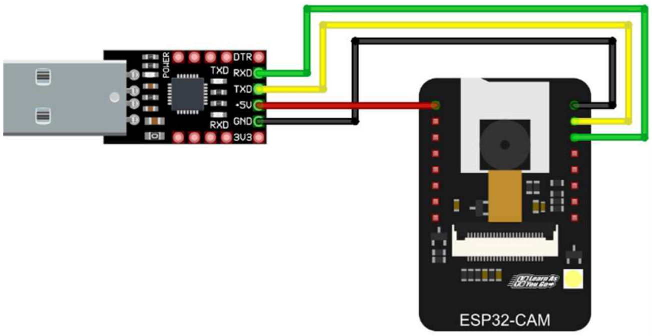

Fig. 2. *Schematic of ESP32-cam*

The next step is to create a bot on Telegram. After installing Telegram on the smartphone, look for BotFather in the search field. Several names of BotFather will appear, and choose the one with a blue tick. Click the "Start" button to start using the bot. Enter the command /newbot to create a new bot, then press enter. Type in a name for the bot, type in "griyapram" for example, and hit the enter key. After giving a name, the next step is to type in the username and end with _bot, for example, "griyapram_bot". If the username already belongs to someone, it has to re-type it to get a username that the person does not already have. After successfully creating, there will be a congratulations message, and it will get the HTTP API code, as seen in Fig 3.

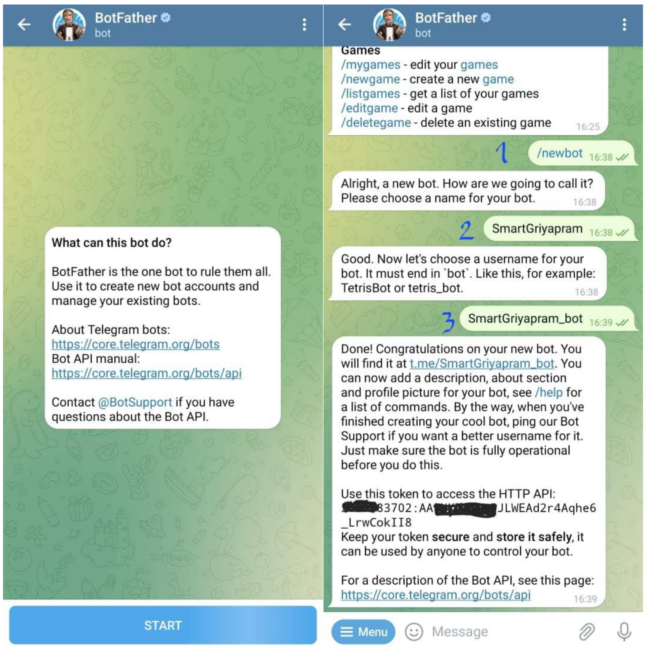

Fig. 3. *Creating bot in Telegram*

The next step is to look for IDBot, which is located on the main Telegram page. If IDBot can not be found, it needs to press the Show More button on the top right. Press the start button to start. Then type /getid to get the username. Copy and paste the API into the program and upload the sketch on the ESP32 cam. Step-by-step making bots on Telegram can be seen as shown in Fig 4.

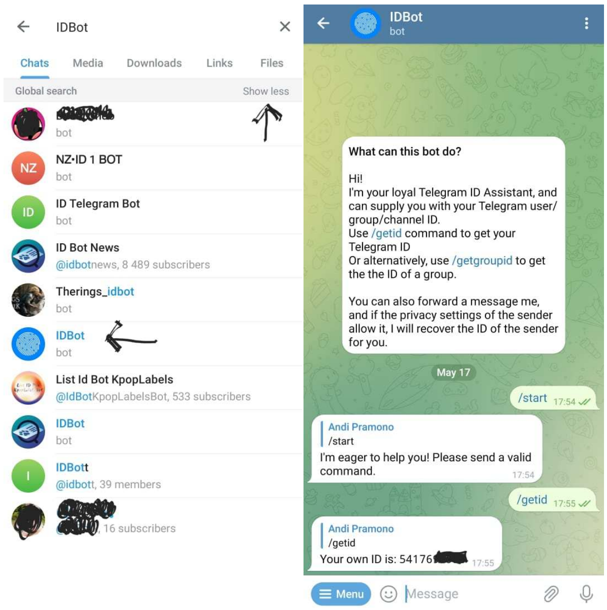

Fig. 4. *Step-by-step making bots on Telegram*

After prototyping, the next step is to try it. In this study, the author started capturing at a distance of 5cm to 20cm. Taking pictures at a distance of 5 to 8 cm produces too close images, so the device's screen was not captured perfectly. Likewise, a distance greater than 12cm will produce relatively small objects. The screen is captured perfectly at a distance of more than 8cm and less than 12cm. The author tries at 9cm and backward every 5mm up to 11cm. The results obtained From several captures are sent to the online OCR software and get text data similar to the data displayed. The image capture and transfer results using OCR software can be seen in Table 1.

TABLE I. IMAGE READING RESULTS USING OCR SOFTWARE

Distance	*Image*	*OCR result*
9cm		AR QUALITY DETECTOR HCHO 0.001 man mg/m TVOC 0.0 14 mgim PM2.5 28 ugim PM10 36 ug/m3 CO 8 CO2 Good 1 ppm 400 ppm Sight Maderate Sefou
9.5cm		AR QUALITY DETECTOR HCHO 0.004 mg/im TVOC 0.0mgim PM2.5 28 ug/m3 PM10 36 ugim CO 1ppm CO2 410 ppm Good Sight Moderate Serious

Distance	*Image*	*OCR result*
10cm		AR QUALITY DETECTOR HCHO 0.002 mg/m TVOC 0.009 mg/m PM2.5 20 ug/m3 PM10 25 ug/m3 CO 1 ppm CO2 410 ppm Good Sight Moderate Serous
10.5cm		AIR QUALITY DETECTOR HCHO 0.001 mg/m TVOC 0.0 15 mg/m PM2.5 22 ug/m3 PM10 28 ug/m3 CO 1 ppm CO2 403 ppm Good Sight Maderate Serous
11cm		AIR QUALITY DETECTOR HCHO 0,001 mg/m TVOC 0.0 15 mg/m PM2.5 28 ugim PM10 36 ugim CO 1 ppm CO2 402 ppm Good Sight Madurate Serbus

From Table 1, the results are more readable when read at a distance of 10.5cm. At a distance of 9cm, the HCHO of 0.001 mg/m3 needs to be read more perfectly. Likewise, it happened to TVOC. At this distance, the arrangement of the writing could be more regular. At a distance of 9.5cm, the writing starts to be neatly arranged, but it still needs to be perfectly legible on the unit. The writing arrangement looks neater at a distance of 10cm, and the units, such as "36 ugim" have changed to 20 ug/m3. At a distance of 10.5 cm, the reading accuracy is almost the same at a distance of 10 cm. The difference between the two is that the text on the title is more legible at a distance of 10.5cm, but this is not a serious problem. At a distance of 11cm, there is a decrease in reading quality. At this distance, the reading accuracy is almost the same as the reading accuracy at a distance of 9.5cm. The experimental picture for determining the reading distance looks like Fig. 5.

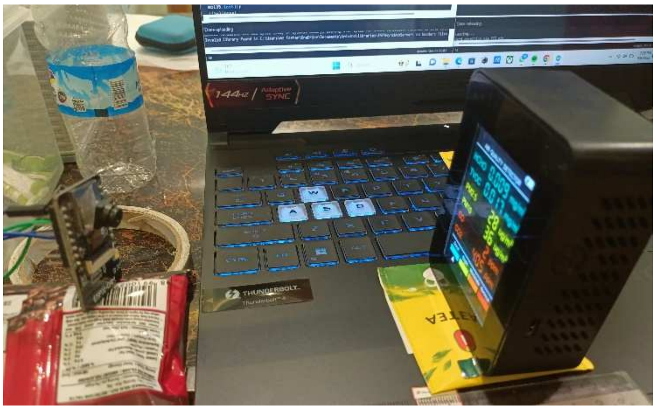

Fig. 5. *Determining the reading distance*

The author also plans to do another experiment for IAQ monitoring. Other devices can have larger or smaller dimensions than the current experimental results. Because of that, the author decided to make a holder whose distance between the ESP32 cam and IAQ monitoring is no more than 15cm.

B. Converting image into data log

With internet download speeds of up to 13 Mbps and upload speeds of up to 6 Mbps, image files that are, on average, 82-88 KB in size can produce text in 7-8 seconds. If an image is taken every 5 minutes, it means that in one day, it will produce 288 images. Furthermore, another process is still converting images to text, which takes 34 minutes. It will take longer with other tasks, such as copying text into a spreadsheet. These are the consequences of using affordable technology. In subsequent research, the software can be developed to reduce the time converting images to text.

This data, in the form of numbers, can then be transferred to a spreadsheet. This data can also look like a graph, according to the selected appearance. This log data will give the user a track record with a relatively small file size because it only displays numbers. Data in the form of images sent on telegrams can be downloaded and stored on a computer, considering that telegrams can be run on personal computers or notebooks.

C. Manufacturing ESP32-cam and IAQ monitoring holder

The ESP32-cam board measured 27mm long, 40.5mm wide, and 1.7mm thick. In reading this dimension, the author uses a digital sketch match. In addition, this board is also equipped with an antenna to strengthen the signal. This antenna is placed upright next to the ESP32 cam holder. This antenna requires a holder with a diameter of 6mm and a thickness of 2mm. As for the monitoring device, the author made a flat design so that the IAQ monitoring device can stand perfectly. So that the two devices, the monitoring device and the ESP32-cam board can be shifted, the author creates a track. The author uses the 3D modeling software Sketchup in the manufacturing process. Then the model is saved in .stl format, and the printing process is carried out using a 3D printer machine. Design details can be seen in Fig. 6.

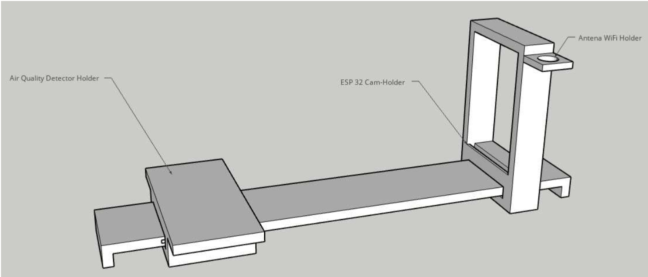

Fig. 6. *ESP32-cam and IAQ monitoring holder design*

IV. CONCLUSION

IAQ monitoring devices equipped with data logs, which are relatively expensive, can be replaced with simple IAQ monitoring devices, which are relatively inexpensive. As for the data record itself, it is sent via the Telegram social media application in the form of a photo. The series of photos can be converted into text, which can later be saved in CSV format as log data. By having this log data, it can be processed into various kinds of graphs.

Design thinking plays an important role in this research. Starting with the problems that exist in the community and being given a solution in the form of a prototype is a concrete step toward solving them. This testing stage is ongoing because it still needs design development for more optimal results, be it hardware design such as device holders or software processing data processing. Hardware-wise, the reading process can be further developed by replacing the camera on the ESP32-cam with a camera that has autofocus so that the reading results are more precise and the OCR conversion process can work faster. The next research phase can also focus on how software integrated with OCR can read the image and send the results in text form. Thus the data sent is relatively small and can be directly processed with a spreadsheet.

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