Design Prototype Detector of Temperature, Humidity, and Air Quality using Sensors, Microcontrollers, Solar Cells, and IoT

Rancang Bangun Prototipe Detektor Suhu, Kelembaban dan Kualitas Udara menggunakan Sensor, Mikrokontroler, Sel Surya dan IoT

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Abstract

Environment monitoring refers to the process, tools, and techniques to observe the quality of the environment. This research discussed the prototype detector of temperature, humidity, and air quality in a scope of hardware design. The components consist of sensors, and microcontrollers with electricity and solar cells as power supplies. The sensors used a DHT22 as the temperature and humidity sensor module and the MQ135 air quality sensor module which are connected to two types of microcontrollers, namely Arduino Uno R3 and Wemos ESP32 for data processing. The prototype has a Wi-Fi modem that can provide a connection to the internet. This prototype can be used as a tool to detect and monitor the environmental changes related to temperature, humidity, and air quality whether indoors or outdoors. The prototype is designed to be integrated with IoT platforms so that data can be sent to the smartphones and then viewed by the users. With the support of the IoT platform, the value of temperature, humidity, and air quality can be monitored easily in a real-time. The design of this prototype can potentially be implemented indoors or outdoors to observe the changes in the environment.

Keywords— environmental monitoring, IoT platform, Arduino, Wi-Fi modem, circuit schematic

Abstrak

Pemantauan lingkungan mengacu pada proses, alat dan teknik untuk mengamati kualitas lingkungan. Penelitian ini membahas tentang prototipe pendeteksi suhu, kelembaban, dan kualitas udara dalam lingkup perancangan perangkat keras. Komponennya terdiri dari sensor, dan mikrokontroler dengan listrik dan sel surya sebagai sumber tenaganya. Sensor tersebut menggunakan DHT22 sebagai modul sensor suhu dan kelembaban serta modul sensor kualitas udara MQ135 yang dihubungkan dengan dua jenis mikrokontroler yaitu Arduino Uno R3 dan Wemos ESP32 untuk pengolahan data. Prototipe ini memiliki modem Wi-Fi yang dapat menyediakan koneksi ke internet. Prototipe ini dapat digunakan sebagai alat untuk mendeteksi dan memantau perubahan lingkungan terkait suhu, kelembaban, dan kualitas udara di dalam maupun di luar ruangan. Prototipe dirancang untuk terintegrasi dengan platform IoT sehingga data dapat dikirim ke smartphone dan kemudian dilihat oleh pengguna. Dengan dukungan platform IoT data suhu, kelembaban, dan kualitas udara dapat dipantau dengan mudah secara real-time. Prototipe yang dirancang ini berpotensi diimplementasikan di dalam atau di luar ruangan untuk mengamati perubahan lingkungan.

Kata kunci— pemantauan lingkungan, IoT platform, modem Wi-Fi, skema rangkaian

1. INTRODUCTION

A healthy environment greatly influences the physical health of all living creatures. The important factors that support physical health are ideal temperature, normal humidity level, and clean air quality. The temperature should be comfortable, and the humidity should be controlled to avoid excess moisture or dryness. Poor air quality can be caused by various factors, such as pollutants, allergens, and mold, and can harm people's health [1]. Based on reference [2] ideal indoor temperature range is between 17.7°C (64°F) to 23.8°C (75°F). Reference [3] informs that the optimal outdoor temperature range is between 20°C (68°F) and 24°C (75°F). Regarding humidity, its level ware varies from place to place, and seasonally more humidity during the summer and less during the winter [4]. The same reference also informs that the comfortable humidity level outside is between 30% and 50%. Article [5] provides information that according to the Environmental Protection Agency, the best indoor relative humidity is between 30% to 50%, and should never exceed 60%. Other studies suggest 40% to 60% is a better range. Regardless, 60% seems to be the agreed-upon threshold for indoor humidity.

A healthy standard of temperature, humidity, and air quality is crucial to humans. But more often it neglected to be measured. This research aims to design a prototype of a detector as a measurement tool for temperature, humidity, and air quality. The prototype could gather data from the environment whether indoor or outdoor to inform the user through IoT platforms.

The Internet of Things (IoT) is a constantly evolving concept that efficiently supports human daily activities by integrating devices [4]. Modern equipment that can assist humans in obtaining the information they need about their surroundings was made possible by the advancements in information and communication technology.

"This research is an extension of previous research which focused on air quality monitoring using sensors, microcontrollers, and IoT platforms." The researcher conducted research [6-10] which focused on air quality monitoring using sensors, microcontrollers, and IoT platforms. The other research [11] discussed temperature and humidity in a server room with Blynk as an IoT platform. Research [12] builds a prototype to detect smoke and flame using Blynk. Research [13] discussed air pressure detection on vehicle tires with two IoT platforms, Blynk and ThingSpeak.

There are several related research to support this research. Research [14] presents a review of air quality systems with various parameters such as data storage, power sources, visualization technologies, processing, and sensors. Research [15] presents the design and development of an outdoor unit prototype IoT-based weather and air quality monitoring station that has a Wi-Fi module to gather and send data through the IoT ThingSpeak channel. Research [16] also discusses IoT-based portable weather monitoring using ThingSpeak and a mobile app that can measure temperature, pressure, humidity, altitude, Particulate Matter 2.5 (PM2.5), Particulate Matter 10 (PM10) level, Volatile Organic Compounds (VOC), and Carbon Monoxide (CO) level. Research [17] describes the sensor node architecture applicable for general monitoring systems and a review of different current low-cost measurement systems for outdoor air quality monitoring. Research [18] discussed open-platform sensor nodes for Agrivoltaics considering the need for the power to support the system. Research [19] discussed air quality monitoring framework systems using IoT and batteries with solar panels. Research [20] proposes a low-cost pollution measurement station for outdoor and indoor which measures air pollution, noise, light pollution, and also relative humidity, and ambient temperature.

The related research mentioned previously described how the prototype is designed, developed, and implemented in its scope. Specifically, this research aims to build a prototype unit as a monitoring device of temperature, humidity, and air quality that has a Wi-Fi connection using solar power or electricity power that can be used indoors or outdoors.

2. RESEARCH METHOD

Researchers build a hardware prototype based on a prototyping model. There are several steps in this hardware development process, including communication, quick plan, and modeling, quick design, construction of prototype, deployment delivery, and feedback [21]. The prototyping model is used to create a dynamic system that is more adaptable and effective. This model is suitable for developing a hardware prototype.

This research begins with a communication process to determine goals and quick planning to identify needs and modeling (quick design modeling) of the system being designed. The next stage is the construction of a prototype which is related to hardware assembly and programming. After the hardware and program have been created, the next stage is to present the system for testing and evaluation (deployment delivery and feedback) by potential users to get input regarding the system created and for further development.

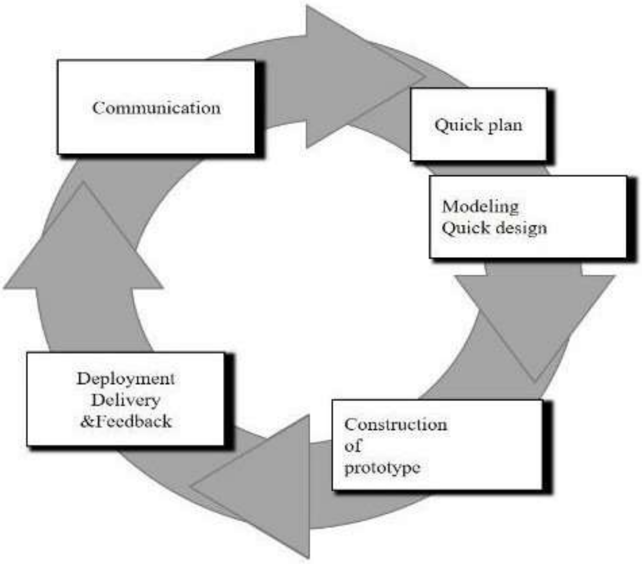

Figure 1. Prototype Model

3. RESULTS AND DISCUSSION

This section discusses the results of research and tests that have been carried out as the results of system design, system implementation results, and system testing.

3.1 System Design

This sub-section describes the design of the hardware which developed. The prototype was built with several main components such as microcontrollers, sensors, step-down converter, modem USB GSM Wi-Fi, solar cells with Accu battery, and solar charge controller. Microcontrollers [22] is the main processing component. There are two microcontrollers used in the prototype namely Arduino Uno R3 [23] and Wemos ESP32 [24]. The use of each board of the microcontroller is shown in Figure 2.

Sensors can detect or measure something that is used to convert mechanical, magnetic, heat, light, and chemical changes into voltage and electric current. The sensor itself consists of a transducer with or without an amplifier or signal processor which is formed in a sensing system [25]. In this system, the prototype uses two types of sensors namely MQ135 as air quality sensors [26] and DHT22 [27] as temperature and humidity sensors.

A power converter LM2596 [28] is used to provide all the active functions for a step-down (buck) switching regulator. This component provided a supporting function for the power supplies. The power supply [29] is a provider of power to activate the system. This prototype uses electricity as the main source of power supplies and solar cells [30] as supporting power supplies.

When the prototype is placed outdoors without an electricity connection then it can use solar cells as power sources.

Figure 2 shows the system design of the prototype detector of temperature, humidity, and air quality in stages and can be explained as follows.

1. The power supply uses electricity and solar cells with batteries. The main power source uses electricity. Solar cells with batteries function as a backup power source that provides power to the equipment.
2. The power supplies are connected to step-down converter LM2596 as a voltage regulator to provide the function for converting a higher input voltage to a lower output voltage. The LM2596 is commonly used in various electronic devices and power supply applications. In this design, the LM2596 supplies power to the components of microcontrollers Arduino Uno and Wemos ESP32 which then pass on the power to the sensors MQ135 and DHT22.
3. The LM2596 is used to power up the modem USB Wi-Fi through an additional USB port.
4. The DHT22 and MQ135 sensors can detect temperature, humidity, and air quality such as CO, CO2, NH4, NOX, NH3, Acetone, Toluene, and Ethanol.
5. Arduino UNO R3 provides instructions to sensors to detect temperature, humidity, and air quality. The results are sent to the Arduino UNO R3 board and then processed.
6. Arduino UNO R3 sends data to Wemos ESP32.

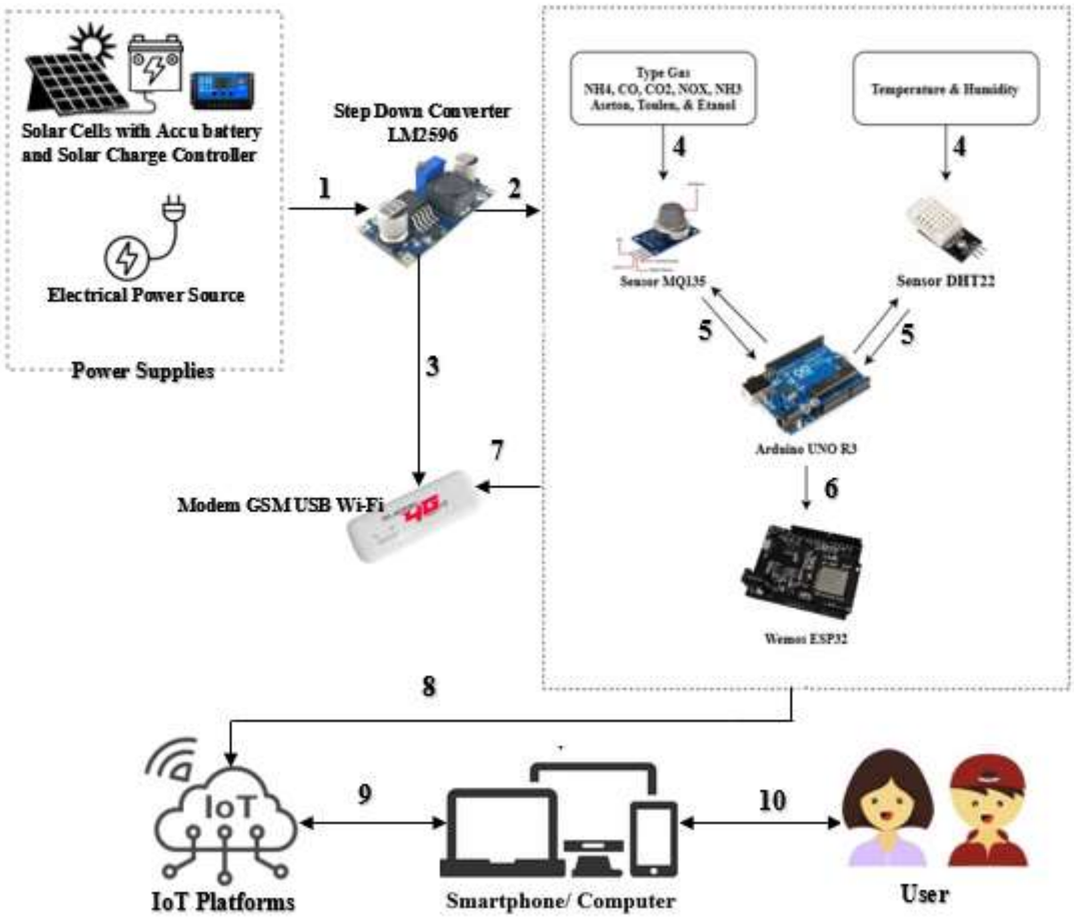

Figure 2. System Design with Hardware Components

7. The prototype connected to the modem USB Wi-Fi with Wemos ESP32 which has a Wi-Fi module. This gives the prototype detector the ability to send data sensed by the sensors to the cloud or the IoT platform for further development and implementation.
8. The prototype sends the data read from sensors to the IoT platforms.

9. The IoT platforms can send the data to the computer or smartphone.
10. The user can access the data of temperature, humidity, and air quality from the smartphone or computer.

Figure 3 shows the use case diagram of the system. A use case diagram is a diagram that explains the flow, functions, and interaction processes between components. The use case mainly shows how the prototype is connected to the two IoT platforms. The first IoT platform can send notifications to users while the second IoT platform allows users to view graphics data of temperature, humidity, and air quality.

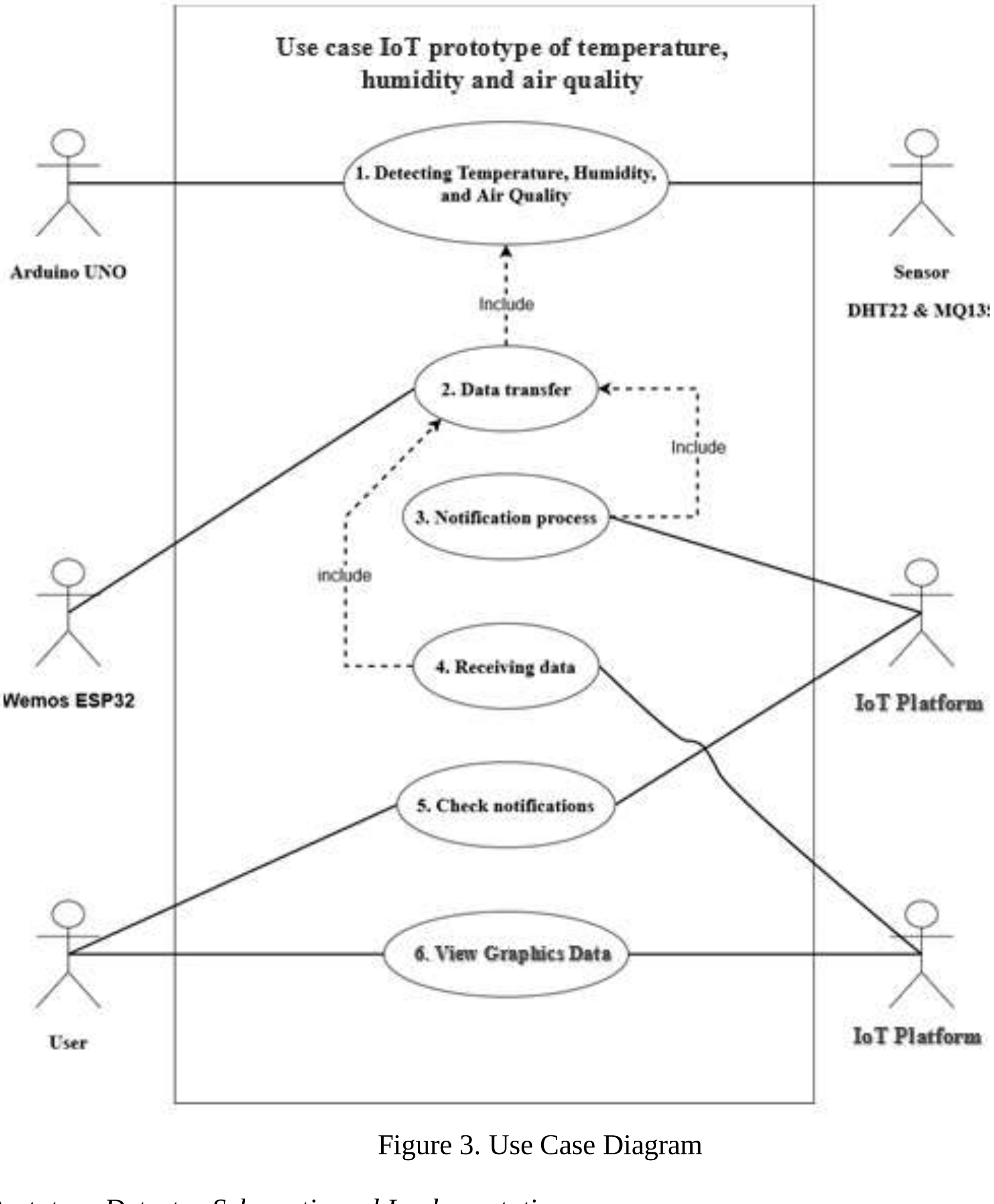

Figure 3. Use Case Diagram

3.2 Prototype Detector Schematic and Implementation

Figure 4 is a schematic of the prototype detector of temperature, humidity, and air quality using IoT which consists of a MQ135 sensor module, DHT22 sensor module, solar panel, battery, relay, stepdown, solar charge controller, USB cable, USB modem Wi-Fi, adapter, jack DC connector, Arduino UNO R3, and Wemos ESP32.

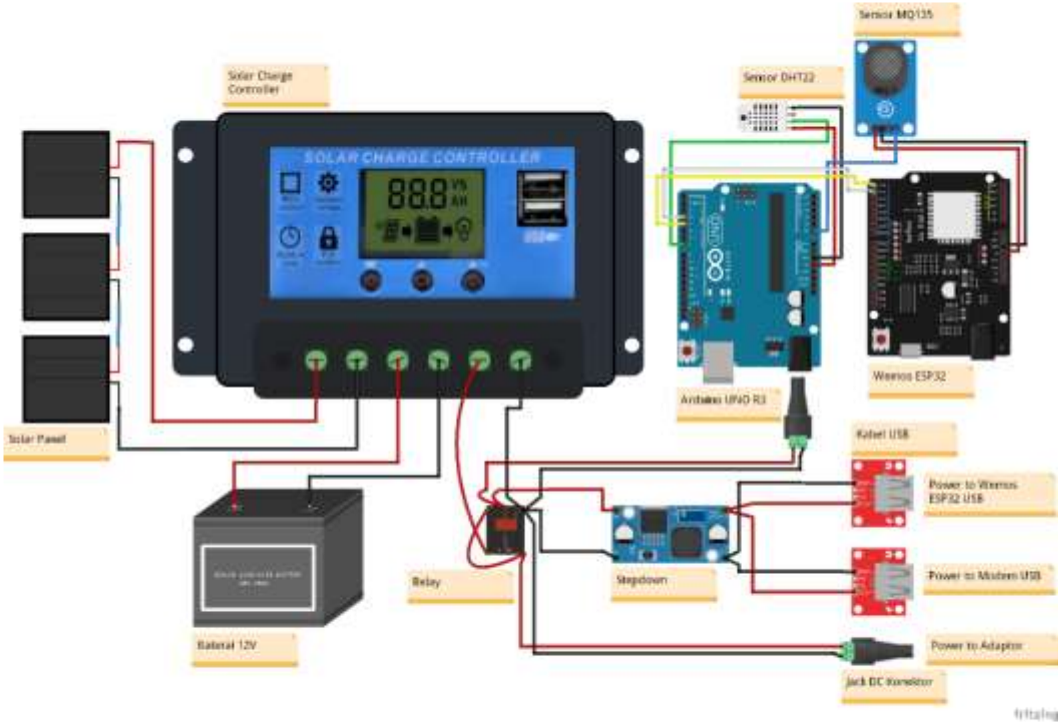

Figure 4. Prototype Detector Circuit Schematic

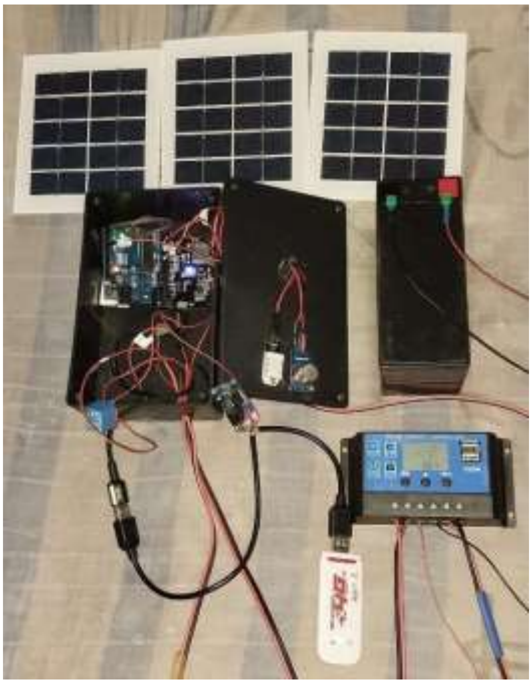

Figure 5. Hardware Implementation

Figure 5 show the hardware implementation of the prototype detector. Figure 6 indicate each component as a part of the prototype.

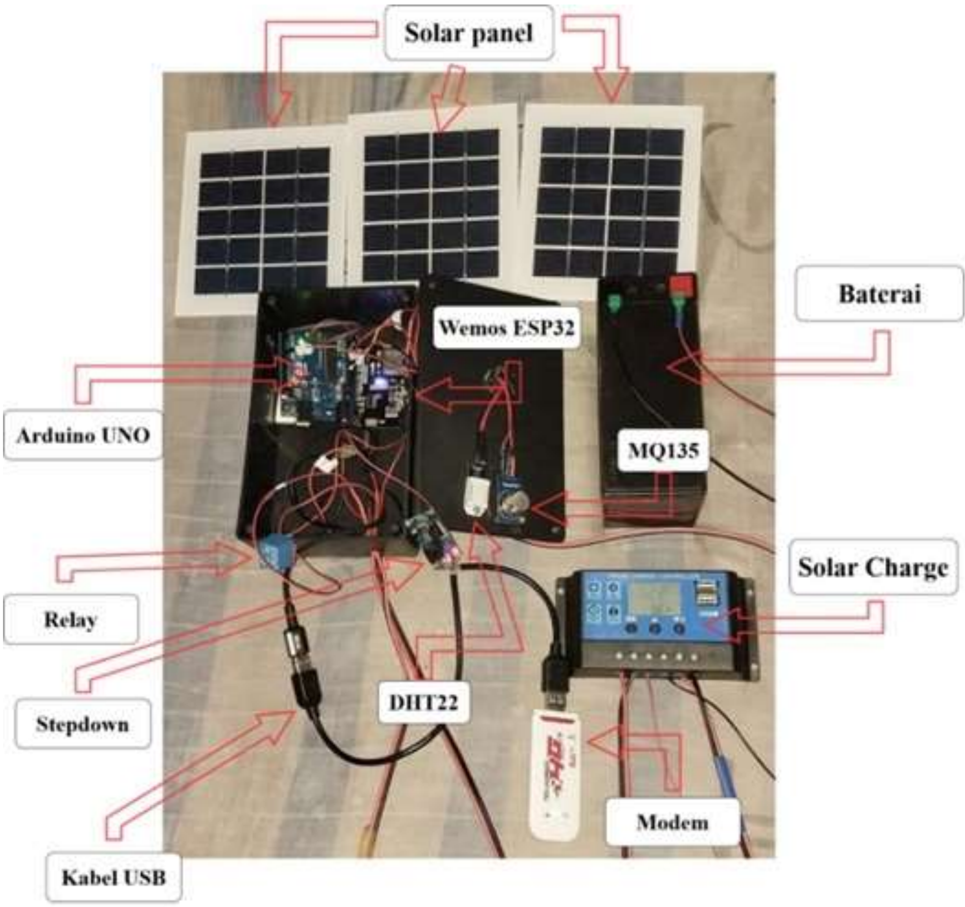

Figure 6. Prototype detector Hardware

3.3 System Testing

The testing process is whether the application is functioning properly or not. Table 1. shows the results of the final testing of the system.

Table 1. Final Testing of the system

Components	Conditions	Process	Results
Sensor MQ135 & DHT22	The sensors are in the standby mode.	The sensor detects the value of temperature, humidity, and air quality.	The sensor successfully detects temperature values in Celsius, humidity in percentage units, and air quality in carbon monoxide units. The sensors send the detection results to the Arduino UNO R3.
Arduino UNO R3	Arduino is active and connected to the sensors.	Analog and digital data from sensors is received by Arduino and the data is	Arduino successfully processes the data and sends it to Wemos ESP32.

		processed according to the function.	
Wemos ESP32	Wemos is active and requests sensor data on Arduino.	TX (Transmit) and RX (Receive) data are used for communication between Wemos and Arduino. So Wemos can send commands and receive data from Arduino.	Wemos successfully received data from Arduino and sent it to Blynk and Thingspeak.
IoT Platforms	IoT platforms have been configured on the smartphone/computer and connected to Wi-Fi through the modem GSM USB Wi-Fi.	Wemos sends the processed data via the internet to the IoT platforms and then sends the data to the user.	The information about temperature, humidity, and air quality is successfully displayed on the IoT platforms.
User	Users use smartphones or computers connected to the internet to monitor the temperature, humidity, and air quality based on the data from the IoT platforms.	IoT platforms can send information to user devices.	The information on temperature, humidity, and air quality is successfully displayed to the user.

4. CONCLUSION

This study aims to design and build a prototype detector as an alternative tool for environmental monitoring that detects the value of temperature, humidity, and air quality. Based on the testing and evaluation, it can be concluded that the prototype is capable of detecting and recording data from the sensors, processing in the microcontroller, and displaying information through the IoT platform. With this prototype, it is projected that it can be used as a tool to monitor the environment parameters namely temperature, humidity, and air quality. This prototype is designed to be used in an outdoor environment because it is equipped with solar cells and electricity but also can be used indoors.

5. FUTURE RESEARCH

Future research will be conducted by using the prototype in indoor or outdoor environments. The prototype needs improvement in the design of a durable case to protect its components from the weather or environment changing especially when placed outdoors. The prototype will be projected to be used in the next research as a monitoring tool that can compare the value of temperature, humidity, and air quality in different locations. The objective of future research is that using the prototype can raise awareness of environmental changes that can have an impact on humans.

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