Temperature and Humidity Monitoring Prototype based on the Internet of Things (IoT) to Improve Awareness of Air Conditions at Villa Tanty

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ABSTRACT
Unmeasured changes in air conditions can affect the health and comfort of the environment at Villa Tanty. The limited availability of indoor temperature and humidity monitoring devices makes it difficult for the caretaker and owner to obtain this information accurately and in real time. Therefore, this study aims to design and develop an Internet of Things (IoT)-based temperature and humidity monitoring system at Villa Tanty located in Cimacan Village that is integrated with the Internet of Things (IoT). This prototype uses a DHT11 sensor, an LDR sensor, and an ESP8266 microcontroller. The research method used is Research and Development (R&D) with a 4D development model, which consists of four stages; however, this study only includes three stages, namely (1) Define, (2) Design, and (3) Development. In the definition stage, an analysis of the needs and problems of Villa Tanty, Cimacan Village, regarding the monitoring system is carried out. The design stage includes hardware design and application interface. The development stage is carried out by creating and testing the system until it functions optimally. The test results show that the prototype is suitable for use, all components function properly and are capable of sending all parameter data via the Telegram platform.

ABSTRAK
Perubahan kondisi udara yang tidak terukur dapat mempengaruhi kesehatan dan kenyamanan lingkungan di Villa Tanty. Keterbatasan alat pemantauan suhu dan kelembapan dalam ruangan membuat penjaga dan pemilik sulit memperoleh informasi tersebut secara akurat dan real-time. Oleh karena itu, penelitian ini bertujuan untuk merancang dan mengembangkan sistem pemantauan suhu dan kelembapan berbasis Internet of Things (IoT) di Villa Tanty yang terletak di Desa Cimacan yang terintegrasi dengan Internet of Things (IoT). Prototipe ini menggunakan sensor DHT11*, sensor* LDR*, dan mikrokontroler* ESP8266*. Metode penelitian yang digunakan adalah Research and Development* (R&D) *dengan model pengembangan* 4D*, yang terdiri dari empat tahap; namun, penelitian ini hanya mencakup tiga tahap, yaitu* (1) *Pendefinisian (Define),* (2) *Perancangan (Design), dan* (3) *Pengembangan (Development). Pada tahap pendefinisian dilakukan analisis kebutuhan dan permasalahan Vila Tanty Desa Cimacan terhadap sistem pemantauan. Tahap perancangan meliputi desain perangkat keras dan antarmuka aplikasi. Tahap pengembangan dilakukan dengan pembuatan dan pengujian sistem hingga berfungsi secara optimal. Hasil pengujian menunjukkan bahwa prototipe layak digunakan, seluruh komponen berfungsi dengan baik dan mampu mengirimkan seluruh data parameter melalui platform* Telegram.

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Internet of Things, Humidity, Temperature

INTRODUCTION

The percentage for each item was calculated as (score obtained)/(maximum possible score) x 100%, and classified as very unsuccessful (0-20%), unsuccessful (21-40%), neutral (41-60%), successful (61-80%), or very successful (81-100%). The total score and percentage for each of the eight items are presented in Table 4.

Indoor air quality plays an important role in human health, thermal comfort, and daily activity productivity (Mumtaz et al., 2021). Polluted air, whether caused by high humidity or inappropriate temperature, can trigger respiratory disorders, fatigue, and decreased cognitive ability (Saini et al., 2020). Because humans spend most of their time indoors, whether at home, in offices, or in other residential buildings, indoor air conditions become a crucial aspect of the well-being and productivity of occupants (Widjaja et al., 2022).

Two main parameters that directly affect indoor air conditions are temperature and relative humidity (RH), as both are related to thermal comfort and indoor micro-environmental conditions (Widjaja et al., 2022). High humidity can be a major trigger for the growth of mold, mites, or other microorganisms, thereby worsening indoor air conditions and increasing health risks for occupants (Nasri et al., 2022). Meanwhile, inappropriate temperatures, whether too low or too high, can disturb comfort (Luo et al., 2021).

In cool areas such as Cimacan, Cianjur Regency, West Java, which tend to have high humidity and lower thermal conditions particularly in rarely used buildings such as villas there is a risk of humidity accumulation due to limited ventilation and low occupant activity. This condition has the potential to increase the relative humidity of the room and trigger condensation on colder surfaces. Prolonged damp conditions can worsen indoor air quality and support the growth of microorganisms (Nasri et al., 2022). A villa that remains continuously damp has the potential to facilitate the growth of mold and bacteria, which then produce spores, allergens, or microbial metabolites that worsen indoor air conditions (Magfira et al., 2025). Mold colony levels increase significantly as relative humidity rises and negatively affect the respiratory health of occupants, such as coughing, shortness of breath, and airway irritation (Nasri et al., 2022).

The Internet of Things (IoT) offers a solution for real-time, automatic, and integrated temperature and humidity monitoring through the use of sensors and communication networks that can be monitored from a smartphone (Mumtaz et al., 2021). The development of an IoT-based indoor air monitoring system enables rapid collection and delivery of environmental data and makes it easier for users to remotely monitor air conditions (Alfirdaus & Martiano, 2024). In addition, an IoT-based indoor air monitoring system can include temperature and humidity parameters as the main indicators of indoor air conditions (Widjaja et al., 2022). The implementation of an IoT prototype at the villa in Cimacan Village enables the monitoring of high or low humidity and temperature, as well as automatic control or alerts to improve awareness of indoor air quality for the health of the villa's occupants in Cimacan Village.

METHODS

This study uses the Research and Development (R&D) method, a research method aimed at developing and producing a product that can be used to solve a particular problem. The development model used refers to Thiagarajan et al. (1974), namely the 4D model consisting of four stages: Define, Design, Development, and Disseminate. However, this study was only carried out up to the Development stage. The research stages carried out based on the 4D model are described as follows:

Define Stage

At this stage, a needs analysis was carried out through site observation and a literature study of a problem to identify the boundaries of development needed. The observation results showed the presence of black mold, a fungus with dark green to deep black coloring that grows in areas with high humidity, low light intensity, and poor air circulation. Environmental factors such as temperature, lighting, and cleanliness greatly determine the quality of the guest experience.



Figure 1. Observation Results at Villa Tanty.

Design Stage

This is the process of designing the device to be developed, starting from selecting the main components, creating the circuit schematic, and formulating a strategy for effective development. The device was designed using an ESP8266 microcontroller as the main component, connecting electronic devices to the internet so that it can efficiently run various IoT functions (Halim & Ardiani, 2024). The use of an internet-based communication platform as a medium for delivering information allows measurement data to be received by users in real time, thereby increasing the effectiveness of the environmental monitoring process (Fadillah & Permata, 2024). In addition, sensors are used to detect temperature and humidity, as well as changes in resistance values based on the light intensity received. The device design also includes integration with the Telegram platform for remote access by users.

Table 1. Tools and Materials

Tools and Materials	Functions
ESP8266	Controls the system operation
DHT11 Sensor	Detects and measures air temperature and humidity
LDR Sensor	Detects and measures light intensity
Project Board	Houses the project circuit
Jumper Cable	Connects pins between components
USB Cable	Connects the microcontroller to the computer for charging and uploading programs from the Arduino IDE to the ESP
Telegram	Facilitates remote device monitoring via gadgets
Arduino IDE	Facilitates communication between the computer and Arduino
Wokwi	Designs and simulates the project circuit

Next, a flowchart was created to describe the process of how the device works. Configuration and initialization are first carried out for each component, namely the ESP8266, DHT11, LDR, and the user's Wi-Fi with the Telegram platform channel. After all components have been integrated, the system begins reading the temperature, humidity, and light intensity via the sensors. Sensor detection continues to repeat until the results meet the criteria or the reading time limit reaches two seconds. The system then sends the data values of the three parameters to the Telegram platform and displays them in the form of a chat bubble and a bar chart. The following is a visualization of the system flowchart.

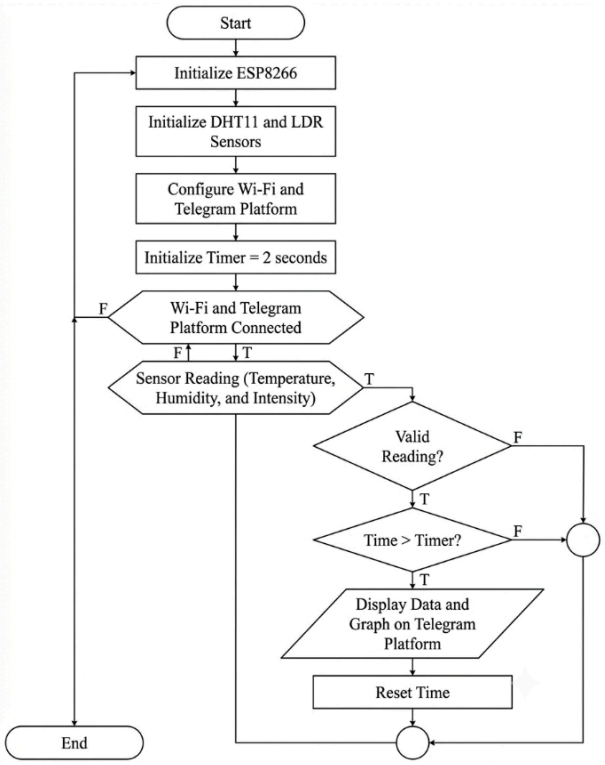


Figure 2. System Flowchart

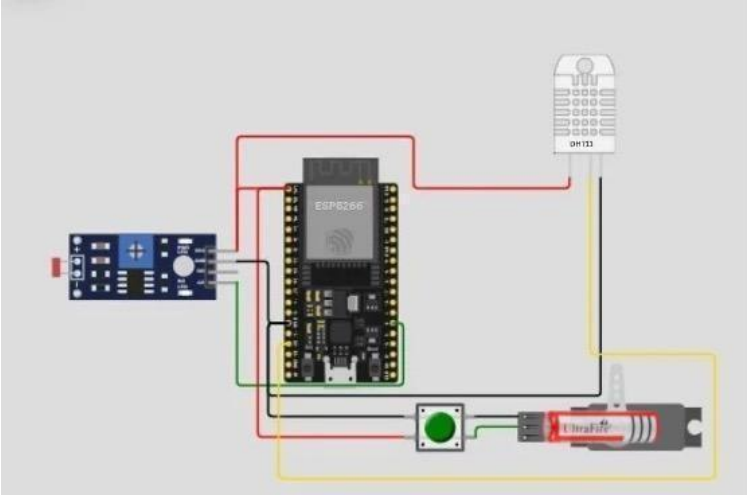


Figure 3. System Circuit Shematic

Development Stage

This stage includes device construction and small-scale testing. Testing was carried out at Villa Tanty in Cimacan Village to analyze the device's performance in detecting sensor readings and displaying the resulting data. This process includes testing the performance of all devices, sensor accuracy, and the effectiveness of the system's operation. Data analysis using a quantitative method with descriptive statistical techniques was then carried out to present the data obtained without generalization.

Dissemination Stage

Namely disseminating and implementing the research product to users, particularly villa owners in highland areas. However, the dissemination stage was not carried out in this study.

RESULTS AND DISCUSSIONS

This study began with a needs analysis through observation of the conditions at Villa Tanty in Cimacan Village and a literature study on IoT-based temperature, humidity, and light intensity sensors. Next, the electronic circuit was designed using a Wokwi simulation, with the DHT11 sensor on a digital pin and the LDR on an analog pin of the ESP8266, followed by system programming that included Wi-Fi configuration and Telegram bot integration for automatic data transmission. Device testing was carried out in three rooms with variations in device placement position and data collection time. The results showed no significant difference in temperature and humidity between positions or times, with temperatures ranging from 25.7–25.9°C, humidity of 64.4–70.8% RH, and light intensity of 652.4–1024 lux. All DHT11 and LDR sensor tests were successful, and the Telegram connection successfully transmitted data in real time, accurately, and accessibly online, although the dissemination stage was not carried out.

Device Design Results

The design of the Internet of Things (IoT)-based temperature and humidity monitoring system to improve awareness of air conditions at Villa Tanty was successfully carried out through the hardware assembly, software programming, and component integration stages. The system was designed with a DHT11 sensor and an LDR sensor. The DHT11 sensor was used to measure the room's temperature and humidity inside the villa, and the LDR sensor was used to measure the room's light intensity. The sensors are connected to the ESP8266 for data processing and transmission to Telegram. The prototype design results are shown in Figure 4.

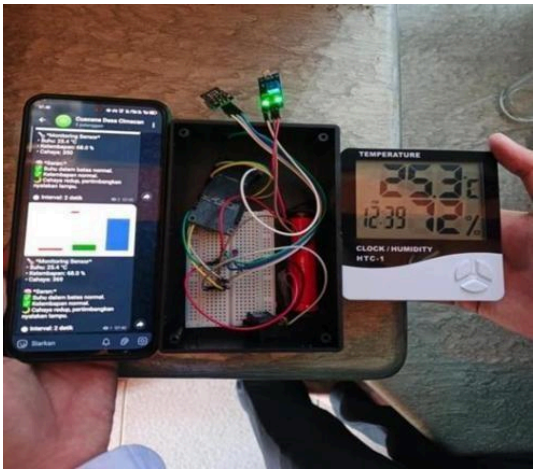


Figure 4. Design Results

Testing Results

In the technology room at 08:00 AM WIB, the average temperature was 25.4°C, the average humidity was 67.6% RH, and the average light intensity level was 407 lux. Next, the 1st-floor women's room showed an average temperature of 23.9°C, an average humidity of 68.4% RH, and an average light intensity level of 895 lux. Meanwhile, women's bedroom 1 showed an average temperature of 24.5°C, an average humidity of 68.2% RH, and an average light intensity level of 609 lux.

Table 2. Testing Results at 8 AM

Room	Temperature (°C)	Humidity (%RH)	Light Intensity (lux)
Technology Room	25.4	67.6	407
Bedroom 1	23.9	68.4	895
Bedroom 2	24.5	68.2	609

In the technology room at 11:00 AM WIB, the average temperature was 25.7°C, humidity was 66% RH, and the light intensity level was 768 lux. Next, the 1st-floor women's room showed an average temperature of 25.9°C,

an average humidity of 64.4% RH, and an average light intensity level of 1024 lux. Meanwhile, women's bedroom 1 showed an average temperature of 25.7°C, an average humidity of 70.8% RH, and an average light intensity level of 652.4 lux.

Table 3. Testing Results 11 AM

Room	Temperature (°C)	Humidity (%RH)	Light Intensity (lux)
Technology Room	25.7	66	768
Bedroom 1	25.9	64.4	1024
Bedroom 2	25.7	70.2	652.4

CONCLUSIONS

Based on the research results, an IoT-based temperature and humidity monitoring device prototype connected to Telegram has been successfully developed. The test results show that all sensors function properly, with a high level of accuracy in temperature and humidity measurement compared to a reference instrument, namely a hygrometer. The system is capable of transmitting temperature and humidity data in real time via Telegram with a two-second time interval and displaying the measurement results automatically. Based on the function tests that have been carried out, this prototype is suitable for use as an IoT-based temperature and humidity monitor at one of the villas in Cimacan Village to improve air-quality awareness at Villa Tanty. This study has a limitation related to the prototype's developer. The suggestion from this study is to create a 3D design to illustrate the shape of the device and to carry out the dissemination stage.

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