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Development of an Android-based Humidity and Air Temperature Monitoring Application for the Greenhouse of Gapoktan Lembang Agri

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ABSTRACT

Unpredictable climate change poses significant challenges for farmers at Gapoktan Lembang Agri in maintaining sustainable production. To support quick and precise decision-making, a mobile-based monitoring system has been developed, enabling real-time monitoring of greenhouse temperature and humidity through an Android application. This system utilizes IoT sensors to measure environmental parameters, with the collected data transmitted to a server via the internet and displayed directly in the application. The application is designed using Jetpack Compose to ensure a responsive and user-friendly interface, even for users with limited technical knowledge. Firebase is employed as a real-time data management platform to guarantee data accuracy and processing speed. Key features include live monitoring, access to historical data, and data export capabilities for further analysis. The system has been successfully implemented and tested in the greenhouse of Gapoktan Lembang Agri, demonstrating its ability to provide real-time monitoring and accurate data. Feedback from users indicates ease of use and the application's effectiveness in helping farmers respond proactively to environmental changes.

Keywords: Mobile, Greenhouse, IoT, Monitoring, Digital Agriculture.

1. INTRODUCTION

Unpredictable climate change has brought significant challenges to the agricultural sector, including the management of vegetable crops in greenhouses. Phenomena such as rising global temperatures, changes in rainfall and extreme humidity affect the stability of microclimates that are key to the successful production of crops such as peppers **(Rozci, 2024)**. Climate variability in Indonesia is closely linked to the positive El Niño and Indian Ocean Dipole (IOD) phenomena, which can disrupt planting schedules and reduce crop yields in drylands **(Apriyana et al., 2016)**. Real-time environmental monitoring technologies are needed to address these challenges and support production sustainability.

IoT systems have been applied in various agricultural sectors to improve efficiency and productivity. However, web-based systems have limited accessibility in the field, especially for farmers who require high flexibility **(Ristian et al., 2022), (Syarief et al., 2017)**. Mobile-based systems provide a practical solution by allowing real-time monitoring of temperature and humidity through smartphone applications, as well as access to historical data for environmental analysis, which is important for crops such as peppers **(Sujadi & Nurhidayat, 2019)**. In addition, the application of IoT enables real-time environmental control to support optimal plant growth **(Swathi Manoharan et al., 2024)**, and this technology also facilitates the monitoring of additional parameters such as water pH, light intensity, and soil moisture through mobile applications, providing more flexibility for farmers **(Hariyanto, 2020), (Austria,A.C., et al., 2023)**.

This research aims to develop a mobile-based monitoring system to support microclimate management in the greenhouse of Gapoktan Lembang Agri. The system uses IoT sensors to measure temperature and humidity, with data sent to a server and displayed through a mobile application equipped with early notification features and historical data analysis for long-term planning (Arafat & Ibrahim, 2020), (Ifa Susuek Anselmus Talli et al., 2023). The system is expected to increase vegetable productivity, reduce the risk of crop failure due to climate change, and become a reference for developing similar technologies in other areas (Swathi Manoharan et al., 2024).

2. METHODOLOGY

2.1 Implementation Method Flow

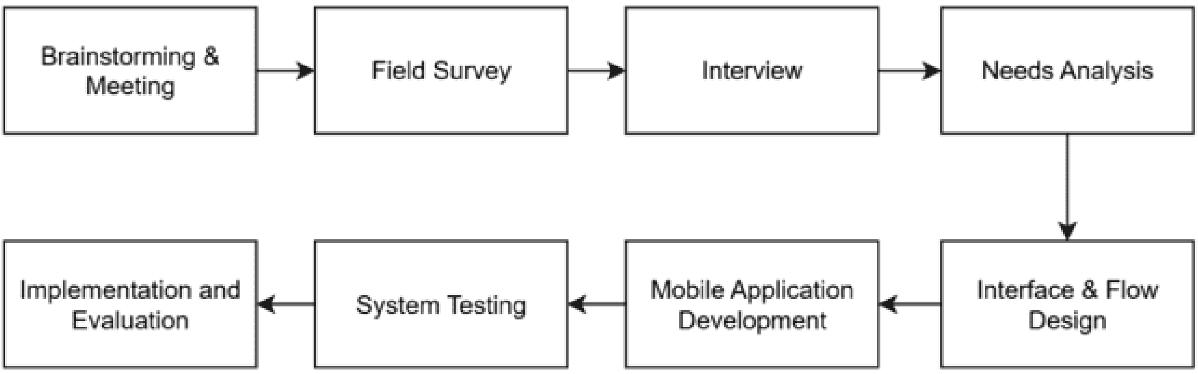

Figure 1. Implementation Method Flow

The flow of the implementation method can be seen in Figure 1 with the following explanation:

1) Brainstorming & Meeting
   The team had internal discussions to determine the objectives, key features, development platform (Android Studio), and data storage (Firebase). Decisions were made to ensure the app is scalable and fits the needs of farmers.
2) Field Survey
   The team conducted a field survey to understand farmers' challenges, such as weather uncertainty and existing infrastructure, including internet access. This data is used to align the app with real conditions.
3) Interview
   In-depth interviews were conducted with farmers to understand their constraints using the technology and desired features, such as watering reminders and weather reports.

4) Needs Analysis
   Data from surveys and interviews were analyzed to determine priority features, such as real-time temperature and humidity monitoring, sensor technical specifications, and infrastructure needs.
5) Interface & Flow Design
   The team designed a simple and intuitive UI/UX with elements such as dashboards, temperature and humidity graphs, and large navigation buttons that are easily accessible to farmers.
6) Mobile Application Development
   The app was developed using Android Studio and Firebase for integration of features such as sensor data, interactive graphs, and secure storage. An access control system was also implemented.
7) System Testing
   The application was tested to ensure data accuracy, interaction with hardware, data security, and ease of use. Feedback from the test run is used for improvement.
8) Implementation and Evaluation
   The application is implemented and evaluated with farmers to ensure its effectiveness in supporting farm management. Feedback is used for app updates and improvements.

2.2 Application Development Workflow

Figure 2. Application Development Workflow

The flow of application development can be seen in Figure 2 with the following explanation:

1) Mobile Design & Development
   The team designed an application with a simple and user-friendly interface (UI/UX) that includes a dashboard to monitor temperature and humidity in real-time, interactive graphs, historical data tables, and additional features such as critical condition notifications and data export.
2) Mobile Development
   Once the design was approved, app development began using Jetpack Compose. Key features such as sensor data collection, data processing, and graph visualization were integrated. The app was also optimized for data security and compatibility across various Android devices.
3) Device & Mobile App Testing
   Testing was conducted to ensure all features were functioning properly, including real-time data display, interaction with sensors, and data accuracy. UX testing involved farmers to ensure the app was easy to use.

4) Device and Program Evaluation and Calibration
Evaluation is conducted to assess whether the app meets user needs. Farmer feedback is used to refine features and calibrate the system to improve app performance and appearance.
5) Maintenance and Improvement
The final stage involves regular app maintenance and updates, including bug fixes, technical support, and feature additions based on user feedback to keep the app relevant and useful.

3. IMPLEMENTATION

3.1 Activity Preparation

The activity began with a planning discussion to define objectives, strategies, and implementation stages for the mobile-based monitoring system as shown in figure 3. Interviews with Gapoktan Lembang Agri's owner were conducted to understand field conditions, farmer challenges, and technical specifications needed to ensure the system meets their needs. Table 1 shows points of the specification needed.

Figure 3. Activity Preparation

Table 1. Activity Preparation

No	Question	Answer	Conclusion
1	Does the system interface need to be simple or interactive?	A simple interface is preferred to ensure ease of use for all groups, including farmers with limited technology.	The system will use a simple design with intuitive navigation.
2	Do users need local language support in the application?	Yes, the use of local languages such as Indonesian will help improve user comfort.	The system will use Indonesian as the primary language.
3	Is historical data important for data management?	Important for long-term analysis and environmental conditions.	The system will provide a dedicated page for historical data that users can access.
4	Does the user need data export?	Data export is required, especially to Excel, for documentation and further analysis.	It will be equipped with a data export feature to Excel.

5	Does the system need to be integrated with certain sensors?	Yes, integration with temperature and humidity sensors to ensure data monitoring accuracy.	The system will support integration with environmental sensors for real-time data.
6	What are the specific requirements for the data display?	Temperature and humidity data need to be presented in real-time and be easy to understand.	The system will use interactive charts to present temperature and humidity data in real-time.

3.2 Implementation of Activities

After interviewing the owner of Gapoktan Lembang Agri, the team designed a simple, intuitive interface with features like real-time graphs, historical data, and Excel export. Using Jetpack Compose and Firebase, the system integrates environmental sensors to ensure accurate data and ease of use for farmers.

3.2.1 Sensor Implementation

Figure 4 shows a wireless sensor system that uses the ESP-NOW protocol to transmit data from multiple sensors to the internet. The Master serves as the center.

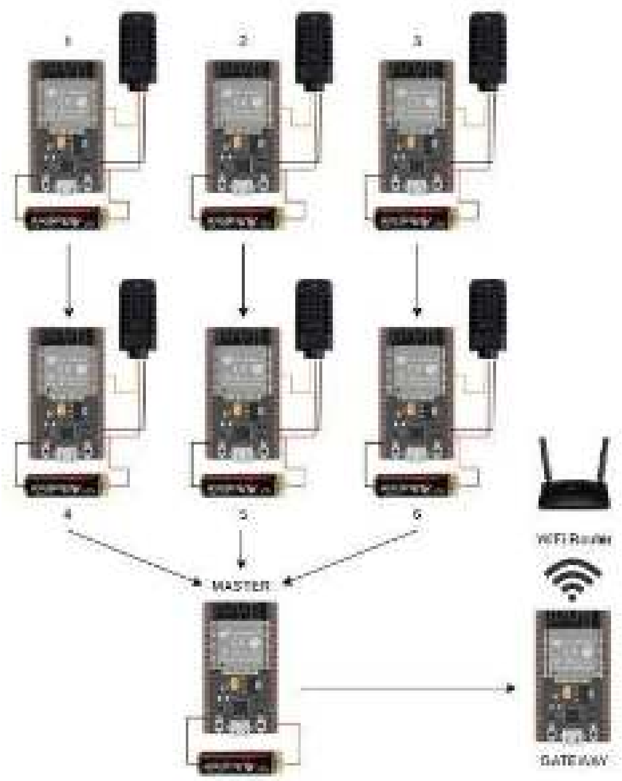

Figure 4. Sensor Implementation

Components:

1. Sensors: Six sensors indicated by numbers 1, 2, 3, 4, 5 and 6.
2. Wireless Module: Each sensor is connected to a wireless module (ESP-NOW).
3. Master: The main module that receives data from the sensors via ESP-NOW.
4. Gateway: The module that receives data from the Master in a wired (serial) manner.

5. Wifi Router: Connects the Gateway to the internet.

Process:

1. Sensors 1, 2, 3, 4, 5 and 6 collect data and send it to their respective wireless modules via ESP-NOW.
2. The wireless module of each sensor sends the data to the Master.
3. The Master receives data from all sensors and sends it to the Gateway via a wired (serial) connection.
4. The Gateway receives the data from the Master and sends it to the internet via a wifi router.

3.2.2 Use case Diagram

Before starting the development of the mobile application, the team first designs the system using Use Cases as shown in Figure 5. This step aims to map the flow and functionality of each feature designed according to user need

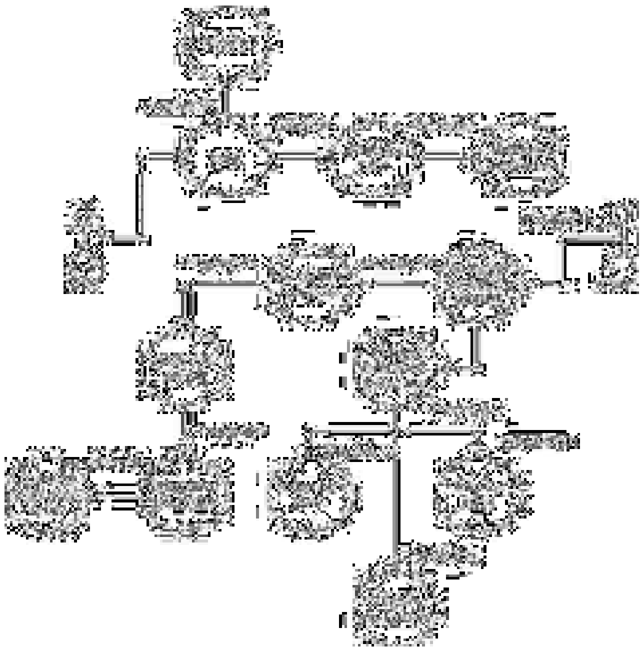

Figure 5. Use Case Diagram

The application includes several components to ensure effective functionality. Users are the primary actors, interacting with sensors that gather data for the application. Key features include user authentication through Login and Register options, allowing secure access. Users can monitor real-time data and historical data through features like Monitoring Data and Monitoring Data History, which display temperature and humidity information.

Data flows from sensors to Firebase Realtime for real-time capture, is stored in MySQL, and can be retrieved via APIs. Historical data is accessible in sortable tables, with options to export data in Excel format. Visualizations include Temperature and Humidity Charts, alongside a 3D model of the greenhouse showing sensor conditions and positions. This integrated design ensures accurate, efficient, and user-friendly monitoring.

3.2.3 Development and Implementation of the System

After the system design and planning have been completed, the next stage is to implement it (slicing UI) and fulfill the backend into the Mobile application. The implementation process begins with the login feature as the gateway for user authentication to fully access the application.

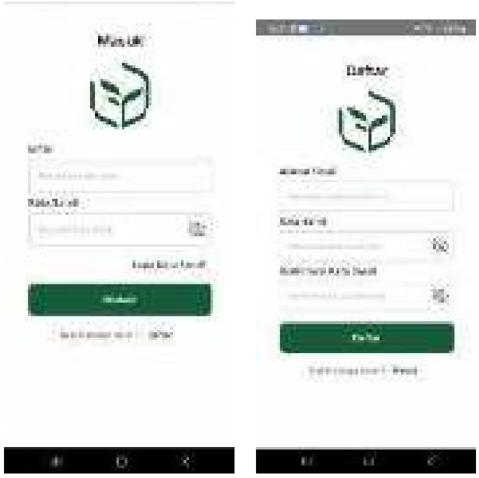

Figure 6 Login and Register Page

The login and registration pages, as shown in Figure 6, feature the Agri Lembang logo and a well-chosen color scheme. The login section prompts users to enter their registered email and password to access the application dashboard, while the registration section allows new users to create an account by providing the required details

Figure 7. Dashboard Page

The Dashboard page after logging in displays information from each existing sensor, then information on detected humidity and temperature, as well as a 3D image and the placement of each sensor, as shown in Figure 7.

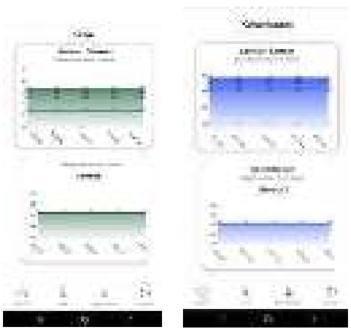

Figure 8 Temperature and Humidity Page

Sensor data collected every five minutes via the Firebase Realtime Database is shown on the data page in Figure 8. There are two different kinds of visualizations for the temperature and humidity sensors: one chart that shows all of the data from the sensors, and several charts that show data from different sensors.

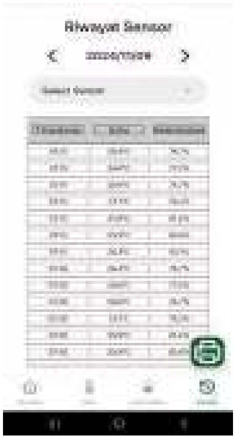

Figure 9. History Page

In Figure 9, the view of the CSV export feature page is shown. This feature allows users to save historical data in a format that can be easily opened and analyzed on various devices. And here is the table containing historical data retrieved using the MySQL API.

3.2.4 Testing

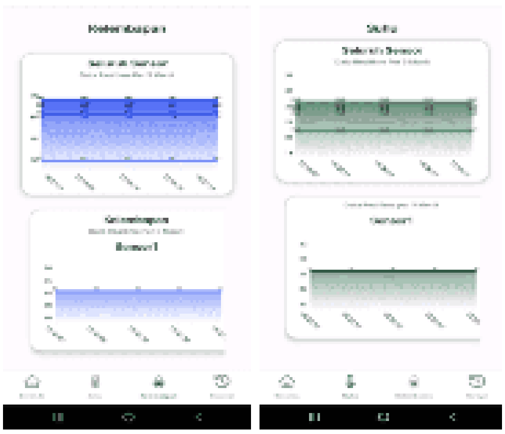

Figure 10. Testing Result

In Figure 10, the page display of the test results for temperature and humidity generated by the sensor is shown. In this test, the displayed data is the direct result of the sensor readings and is pulled directly through Firebase Realtime. This test aims to demonstrate the reliability and responsiveness of the sensor in detecting environmental conditions.

Tests showed a temperature range of 22°C-30°C and humidity of 60%-80%, with 100% of the data successfully displayed to the server accurately within 5 seconds. Before the application, only 75% of the data was recorded manually, but now 100% of the data is recorded, improving the efficiency and accuracy of the system.

3.3 Evaluation & Activity Results

The mobile application was tested to ensure seamless integration with monitoring devices, successfully performing real-time monitoring, data history access, and CSV export. Intensive training was provided to Gapoktan Lembang Agri representatives, covering key features, data management, and monitoring optimization, enabling effective decision-making. The event concluded with documentation activities.

Figure 11. Photo of the team with the Gapoktan Lembang Agri representatives after the training and application evaluation activities.

The application and monitoring devices perform well, but future improvements could include adding sensors for soil pH and light intensity, as well as integrating AI or machine learning for predictive analysis and data-driven recommendations, enhancing agricultural efficiency and productivity.

4. CONCLUSION

Abdimas participants gave positive responses to the developed application. They stated that the app makes it easier to monitor temperature and humidity conditions in the greenhouse in real-time, thus improving the response to environmental changes. One participant mentioned, "The app is very easy to use, even for those of us who are less familiar with technology." In addition, the early notification feature was considered very helpful in anticipating critical conditions that could affect crops. Some participants also appreciated the ease of accessing historical data, which is useful for long-term analysis and planning. Additional feedback from participants included hopes for new features, such as the integration of local weather reports or the addition of sensors for other parameters such as soil pH.

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