

Internet of Things Based White Rumped Shama Egg Incubator

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Abstract

The Magpie Robin is a songbird species with high economic value and is widely cultivated by the community. However, the success rate of hatching of this bird's eggs is still low due to temperature and humidity instability during the incubation process. This study aims to design an Internet of Things (IoT)-based Magpie Robin egg incubator that is able to monitor and control temperature and humidity automatically and in real-time. This system uses an ESP32 microcontroller as a control center connected to a DHT22 sensor, an incandescent lamp as a heater, a DC fan as a cooler, a synchronous motor for automatic egg turning, and an ESP32-CAM camera for visual monitoring inside the incubator. Data is sent to the Blynk IoT platform for remote monitoring via a web dashboard. The development method used is Waterfall, including the stages of requirements analysis, design, implementation, and testing. Based on the results of this test, the tool is able to control the temperature automatically in the range of 37–38°C and humidity of 50–60%, in accordance with the hatching standards for Murai Batu bird eggs, the egg incubator machine operates for 14 days with 4 Murai Batu bird eggs, on the day of hatching 3 eggs successfully hatched and 1 did not hatch, eggs that did not hatch were indicated to be infertile or unfertilized. With this, the Murai Batu egg incubator machine has a success rate in hatching reaching 75%.

Keywords: Automatic Incubator, DHT22, ESP32, Internet Of Things, Magpie Stone

1. Introduction

Magpie Robin (*Copsychus malabaricus*) is one of the most valuable songbird species widely cultivated because of its economic value and high demand in bird competitions. The success of breeding activities is highly dependent on the egg incubation process, which requires stable temperature and humidity conditions to support embryo development. Conventional incubation methods still rely on parent birds or simple incubators, making environmental control less effective and reducing hatching success. Previous studies reported that the optimal incubation temperature for bird eggs ranges from 37°C to 38°C with relative humidity between 50% and 60%. [1]

The rapid development of the Internet of Things (IoT) has enabled automatic monitoring and control systems capable of maintaining incubation conditions in real time. IoT technology allows temperature and humidity data to be transmitted through internet-connected devices, enabling users to monitor incubator conditions remotely and respond immediately when environmental changes occur. [2]

Several previous studies have developed IoT-based egg incubators using ESP8266 or ESP32 microcontrollers integrated with DHT11/DHT22 sensors and the Blynk platform for environmental monitoring. [3] Other studies have demonstrated that IoT technology can improve incubation efficiency through automatic temperature regulation, humidity monitoring, and remote access. [4] However, most existing systems are limited to monitoring temperature and humidity and generally lack visual monitoring features, cloud-based data storage, or are not specifically designed for Magpie Robin egg incubation.

Based on these limitations, this study proposes an Internet of Things-based Magpie Robin egg incubator using an ESP32 microcontroller integrated with a DHT22 sensor, incandescent heating lamp, DC cooling fan, automatic egg-turning synchronous motor, and ESP32-CAM for real-time visual monitoring. Sensor data are transmitted to a web dashboard through a cloud database, allowing users to monitor and control the incubator remotely.

The main contribution of this research is the development of a comprehensive IoT-based incubation system that combines automatic environmental control, real-time visual monitoring, and web-based remote access specifically for Magpie Robin egg incubation. Experimental results demonstrated that the proposed system successfully maintained the incubation temperature at 37–38°C and relative humidity at 50–60%, achieving a hatching success rate of 75%.

2. Research Method

This research focuses on developing an Internet of Things (IoT)-based egg incubator for White-rumped Shamas (*Copsychus malabaricus*) capable of automatically monitoring and controlling temperature and humidity. The system integrates an ESP32 microcontroller, DHT22 sensor, heating lamp, DC fan, synchronous motor, ESP32-CAM, Firebase, and a web dashboard to facilitate real-time monitoring. The research employs the Waterfall model, encompassing requirements analysis, design, implementation, and system testing. Evaluation is conducted through sensor testing, automatic control verification, system integration, and egg incubation trials to assess the device's overall performance.

2.1. System Architecture

The proposed system consists of an ESP32 microcontroller, a DHT22 temperature and humidity sensor, an ESP32-CAM module, a synchronous motor, a DC cooling fan, an incandescent heating lamp, relay modules, Firebase Realtime Database, and a web-based monitoring dashboard. The ESP32 functions as the main controller, processing sensor data, controlling the heating, cooling, and egg-turning mechanisms, and transmitting real-time data to the cloud database via a Wi-Fi connection. The DHT22 sensor continuously measures the temperature and humidity inside the incubator, while the ESP32-CAM provides visual monitoring of the egg incubation process. Hardware configuration, power distribution, and system data flow are illustrated in Figure 1.

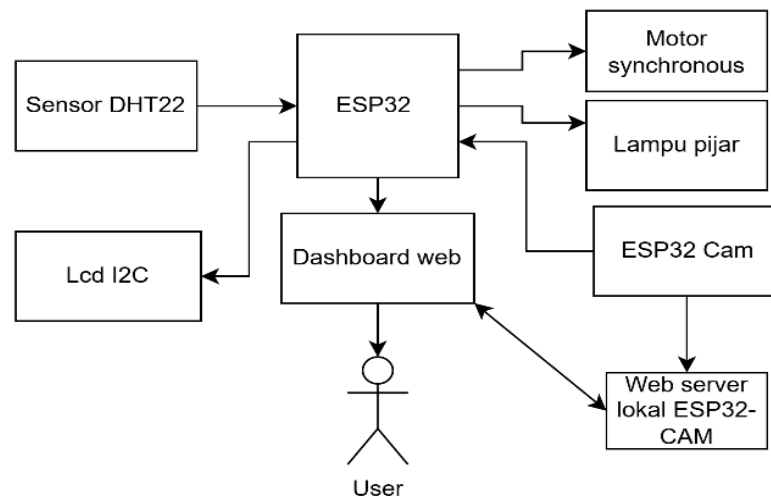


Fig. 1: Architecture of the proposed system

The DHT22 sensor is used to measure temperature and humidity inside the incubator in real-time. With its high measurement accuracy, the sensor is well-suited for automated incubation systems. Sensor readings are transmitted to an ESP32 microcontroller for processing, serving as the basis for decisions regarding the control of the incubator's environmental conditions. Based on the measured temperature and humidity values, the ESP32 automatically activates an incandescent bulb as a heater when the temperature falls below a set threshold and engages a DC fan when the temperature exceeds the optimal limit. Additionally, a synchronous motor is employed to automatically turn the eggs at predetermined intervals, ensuring optimal embryonic development. All sensor data and device status information are transmitted to the Firebase Realtime Database via Wi-Fi and displayed on a web dashboard, while an ESP32-CAM module provides real-time visual monitoring of the eggs inside the incubator.

The proposed incubation system employs an ESP32 microcontroller as the main controller to process temperature and humidity data acquired from the DHT22 sensor and to control all actuators automatically. Two relay modules are used to switch the incandescent lamp as the heating element and the DC fan as the cooling system, thereby maintaining the incubation temperature within the predetermined range. A synchronous motor is utilized to rotate the eggs automatically at predefined intervals, ensuring uniform heat distribution and supporting optimal embryo development. The ESP32-CAM module provides real-time visual monitoring of the incubation process, allowing users to observe egg conditions remotely. Sensor readings and device status are transmitted to the Firebase Realtime Database through a Wi-Fi connection and displayed on a web-based dashboard, enabling real-time monitoring and remote control of the incubator.

2.2. System Workflow

The operational workflow of the proposed system begins with the initialization of all hardware and software components, including the ESP32 microcontroller, DHT22 temperature and humidity sensor, ESP32-CAM module, relay modules, synchronous motor, and the connection to the Firebase Realtime Database. After initialization, the system continuously monitors the temperature and humidity inside the incubator through the DHT22 sensor. The measured data are processed by the ESP32 to determine the appropriate control actions based on predefined temperature and humidity thresholds.

When the temperature falls below the specified range, the ESP32 activates the incandescent lamp through the relay module to increase the incubation temperature. Conversely, when the temperature exceeds the predefined threshold, the DC cooling fan is activated to maintain optimal environmental conditions. The synchronous motor automatically rotates the eggs at predetermined time intervals to ensure uniform heat distribution during the incubation process. Simultaneously, the ESP32-CAM captures real-time images of the incubator, while all sensor readings and device statuses are transmitted to the Firebase Realtime Database and displayed on the web-based dashboard, enabling users to monitor the incubation process remotely in real time.

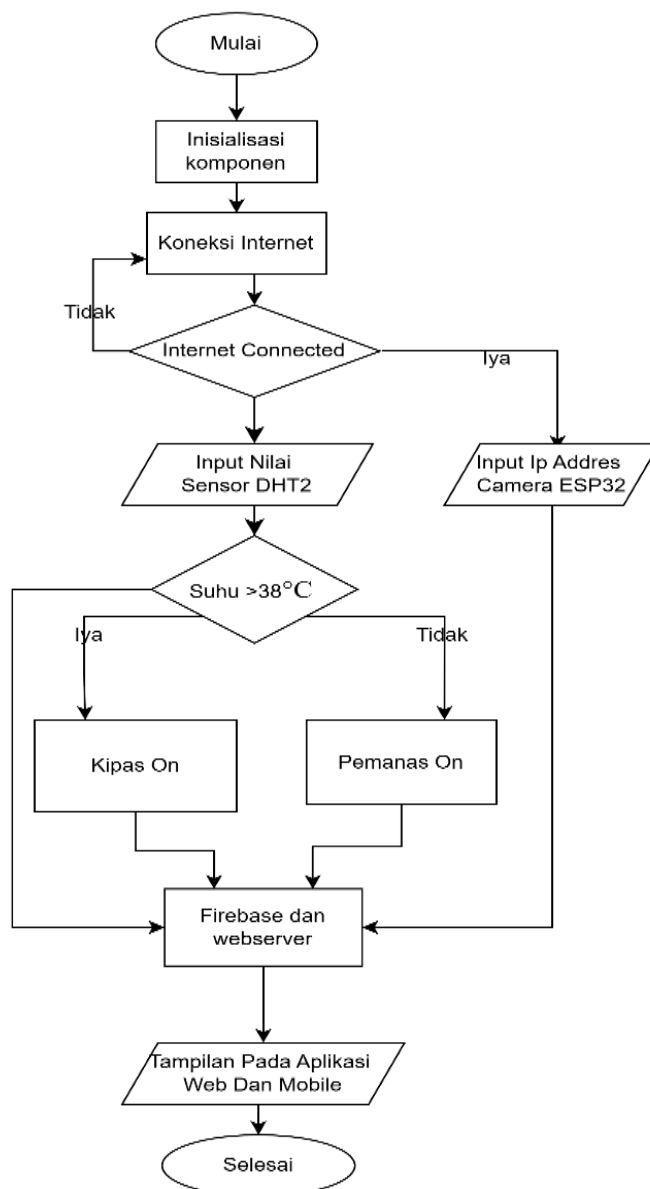


Fig 2: Workflow of the proposed system

After processing sensor data and executing appropriate control actions, the ESP32 continuously updates temperature, humidity, and device status data to the Firebase Realtime Database. The transmitted data is displayed on a web-based dashboard, allowing users to monitor incubation conditions remotely in real-time. Additionally, the ESP32-CAM provides live visual monitoring of the eggs inside the incubator, enabling users to observe the incubation process without opening the unit and disrupting the internal environment. Monitoring and control operations run continuously throughout the incubation period, while a synchronous motor automatically rotates the eggs at predetermined intervals. The system iteratively performs sensor data acquisition, environmental control, data transmission, and visual monitoring until the incubation process is complete.

3. Result and Discussion

3.1. Prototype Implementation

The proposed IoT-based White-rumped Shama (Magpie Robin) egg incubator has been successfully developed by integrating an ESP32 microcontroller, DHT22 temperature and humidity sensors, a relay module, an incandescent heating lamp, a DC cooling fan, a

synchronous motor, an ESP32-CAM module, and Firebase Realtime Database, alongside a web-based monitoring system. The ESP32 serves as the central controller, processing temperature and humidity data, executing automated environmental control algorithms, managing the heating, cooling, and egg-turning systems, and transmitting operational data in real-time to the cloud database. This system enables continuous monitoring and remote oversight of the incubation process, thereby maintaining stable environmental conditions to support optimal embryonic development.



Fig. 3: Physical Implementation of the Developed IoT-Based Magpie Robin Egg Incubator

The hardware is assembled using a modular design based on perfboard to facilitate circuit integration, component installation, and system maintenance. The main control board integrates an ESP32 microcontroller as the central processing unit, a DHT22 temperature and humidity sensor, a relay module, and an I2C LCD screen for local environmental monitoring. The relay module controls an incandescent lamp (acting as a heating element) and a DC cooling fan to maintain the incubation temperature within the desired range. A synchronous motor is connected to the ESP32 to automatically rotate the eggs at preset intervals, ensuring even heat distribution during incubation. Additionally, an ESP32-CAM module is installed inside the incubator to provide real-time visual monitoring of the eggs. The ESP32 communicates with the Firebase Realtime Database via Wi-Fi, allowing temperature, humidity, and system status data to be displayed on a web-based dashboard for remote monitoring and control.

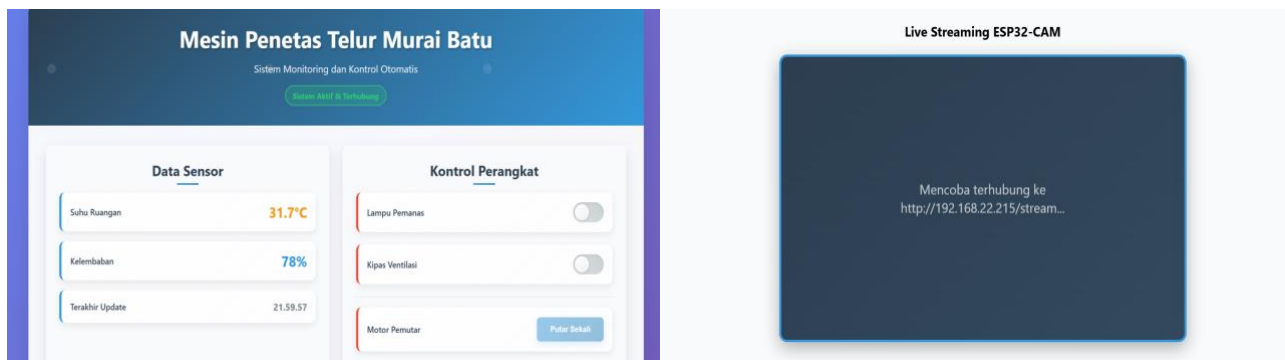


Fig. 4: Web Applications

Furthermore, a web-based monitoring dashboard was developed and integrated with the Firebase Realtime Database to provide real-time monitoring of the incubation process. The dashboard enables users to observe temperature and humidity conditions, monitor the operational status of the heating lamp, cooling fan, and egg-turning mechanism, and access live visual monitoring through the ESP32-CAM module. All sensor readings and system status are updated continuously via a Wi-Fi connection, allowing users to supervise the incubator remotely through a web browser. The successful integration of the ESP32 microcontroller, DHT22 sensor, ESP32-CAM, Firebase Realtime Database, and web dashboard demonstrates the feasibility of implementing an IoT-based intelligent egg incubation system for maintaining optimal environmental conditions during the incubation process.

3.2. DHT22 Sensor Testing

The DHT22 sensor was evaluated to determine its ability to measure temperature and relative humidity inside the incubator. Accurate and stable sensor readings are essential to ensure that the ESP32 microcontroller can automatically control the heating lamp and cooling fan, thereby maintaining optimal incubation conditions. The sensor performance was assessed by comparing the measured temperature and humidity with the predefined incubation parameters.

Table 1: DHT22 Testing Result Sensor

Temperature (°C)	Humidity (%)	System Status
30.0	50	Suhu Awal
34.5	52	Heating ON
36.8	54	Heating ON
37.5	56	Normal
37.8	58	Normal
38.2	60	Colling ON

The experimental results demonstrate that the DHT22 sensor successfully monitored the temperature and humidity inside the incubator throughout the testing process. The ESP32 automatically activated the incandescent lamp when the temperature was below the predefined threshold and operated the DC cooling fan when the temperature exceeded the desired range. Overall, the proposed control system maintained the incubation temperature within 37–38°C and the relative humidity between 50% and 60%, providing suitable environmental conditions for Magpie Robin egg incubation.

3.3. System Integration Testing

The overall system integration testing evaluated the coordinated operation of the ESP32 microcontroller, DHT22 temperature and humidity sensor, relay modules, incandescent heating lamp, DC cooling fan, synchronous motor, ESP32-CAM, Firebase Realtime Database, and the web-based monitoring dashboard. The testing verified that the ESP32 accurately processed sensor data and automatically controlled the heating lamp and cooling fan to maintain the incubation temperature and humidity within the predefined thresholds. In addition, the synchronous motor successfully rotated the eggs at scheduled intervals, while the ESP32-CAM provided continuous real-time visual monitoring. Furthermore, all environmental data and device statuses were transmitted successfully to the Firebase Realtime Database and displayed on the web dashboard, demonstrating reliable system integration and stable remote monitoring throughout the incubation process.

Table 2: Overall System Integration Testing Result

Pengujian	Sistem Monitoring			
	Suhu/ Kelembapan	Internet	Suhu/ Kelembapan	Camera
1	36.5°C/ 61.7%	Connected	Terbaca	Terbaca
2	36.9°C/ 50.2%	Connected	Terbaca	Terbaca
3	37.2°C/ 58.6%	Connected	Terbaca	Gagal
4	38.5°C/59.6%	Connected	Terbaca	Gagal
5	37.5°C/52.6%	Connected	Terbaca	Gagal

The integration testing confirmed that the end-to-end communication between the ESP32 microcontroller, DHT22 sensor, Firebase Realtime Database, ESP32-CAM, and the web-based monitoring dashboard operated as designed. The ESP32 continuously acquired temperature and humidity data from the DHT22 sensor and automatically controlled the incandescent heating lamp and DC cooling fan based on predefined environmental thresholds. The synchronous motor successfully rotated the eggs at scheduled intervals, ensuring uniform heat distribution during the incubation process. In addition, the ESP32-CAM provided continuous real-time visual monitoring, while all environmental parameters and device statuses were synchronized with the Firebase Realtime Database and displayed on the web dashboard with minimal communication delay. The system also maintained stable operation during continuous monitoring and automatically resumed data synchronization after network reconnection, demonstrating reliable performance for long-term IoT-based egg incubation.

4. Conclusion

This study successfully designed and implemented an Internet of Things (IoT)-based Magpie Robin egg incubator capable of automatically monitoring and controlling the incubation environment. The proposed system integrates an ESP32 microcontroller, DHT22 temperature and humidity sensor, relay modules, an incandescent heating lamp, a DC cooling fan, a synchronous motor for automatic egg turning, an ESP32-CAM module, Firebase Realtime Database, and a web-based monitoring dashboard. The ESP32 successfully processed sensor data to regulate the heating, cooling, and egg-turning mechanisms, while environmental data and system status were transmitted to the cloud for real-time remote monitoring.

Experimental results demonstrated that the developed system was able to maintain the incubation temperature within 37–38°C and the

relative humidity between 50% and 60%, providing suitable environmental conditions for Magpie Robin egg incubation. The automatic control system, real-time data transmission, and visual monitoring functioned reliably throughout the testing process. A 14-day incubation experiment using four eggs resulted in three successfully hatched eggs, achieving a hatching success rate of 75%, which indicates that the proposed system effectively supports the incubation process.

Future work may focus on improving the environmental control algorithm to achieve higher temperature and humidity stability, enhancing the web-based monitoring interface, integrating automatic humidity regulation, and evaluating the system using a larger number of eggs and multiple incubation cycles to further improve the reliability and effectiveness of the proposed IoT-based incubation system.

Acknowledgement

The author wishes to express gratitude to the Department of Information Technology at Samarinda State Polytechnic for providing the facilities and support necessary to conduct this research. Special thanks are extended to Wahyuni Eka Sari and Abdullah Hanif for their guidance, constructive feedback, and ongoing support throughout the research process. The author also extends thanks to family, colleagues, and all those who contributed to the successful completion of this research.

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