Smart Farming for Poultry: Enhancing Growth and Efficiency With Low-Cost Internet of Things Solutions

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This article investigates the impact of a low-cost Internet of Things system for autonomous environmental regulation in poultry farming, demonstrating its potential to optimize growth, welfare, and operational efficiency in small-scale production within the Brazilian agricultural context.

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Poultry production has steadily increased in response to the rising global demand for chicken meat. The Food and Agriculture Organization estimates that global chicken consumption will reach approximately 140 million metric tons by 2024.[1] This growing demand has spurred an increase in poultry producers at both the family and industrial scales. However, managing poultry in these environments presents significant challenges. Poultry are highly sensitive to environmental factors within poultry houses, such

as ambient temperature and relative humidity, which directly impact their health and productivity.[2]

For instance, excessively high temperatures can reduce feed intake by increasing thirst and decreasing appetite, ultimately lowering weight gain.[3] High relative humidity, on the other hand, weakens poultry and increases the risk of disease.[4] These challenges are particularly pronounced in tropical countries with consistently high temperatures as well as in northern countries that experience extreme cold for part of the year, complicating the environmental management within poultry houses.

While advanced technologies for monitoring and controlling these environmental factors have been developed, their high cost makes them inaccessible for many small- and medium-sized producers.[5] This financial barrier creates a significant gap between large-scale producers and smaller operators in terms of efficiency and productivity.

In this article, we present the results of a study evaluating a low-cost Internet of Things (IoT)-based information system for poultry management. Our goal is to determine how this system could automate the regulation of key environmental variables, reduce the effort required from producers, and ultimately improve weight gain in poultry. The system's architecture and technological configuration were carefully designed to address these challenges while maintaining affordability for small- and medium-scale producers.

THE IoT-BASED LOW-COST SYSTEM FOR POULTRY RAISING

The proposed low-cost, IoT-based system is designed to effectively improve poultry farming by integrating monitoring, automation, and data analytics into a unified, scalable architecture. This system comprises four core components (Figure 1): the Monitoring Device, the LoRa/Wi-Fi Gateway, the ThingSpeak Cloud, and a custom-built Web Platform. Each component has been meticulously selected and optimized to address the unique challenges of poultry farming, particularly in rural areas with limited connectivity and a critical need for real-time environmental monitoring.

System components

The system components are as follows:

- *Monitoring Device*: At the core of this architecture lies the Monitoring Device, which is responsible for capturing and transmitting key environmental parameters, such as light intensity, temperature, humidity,

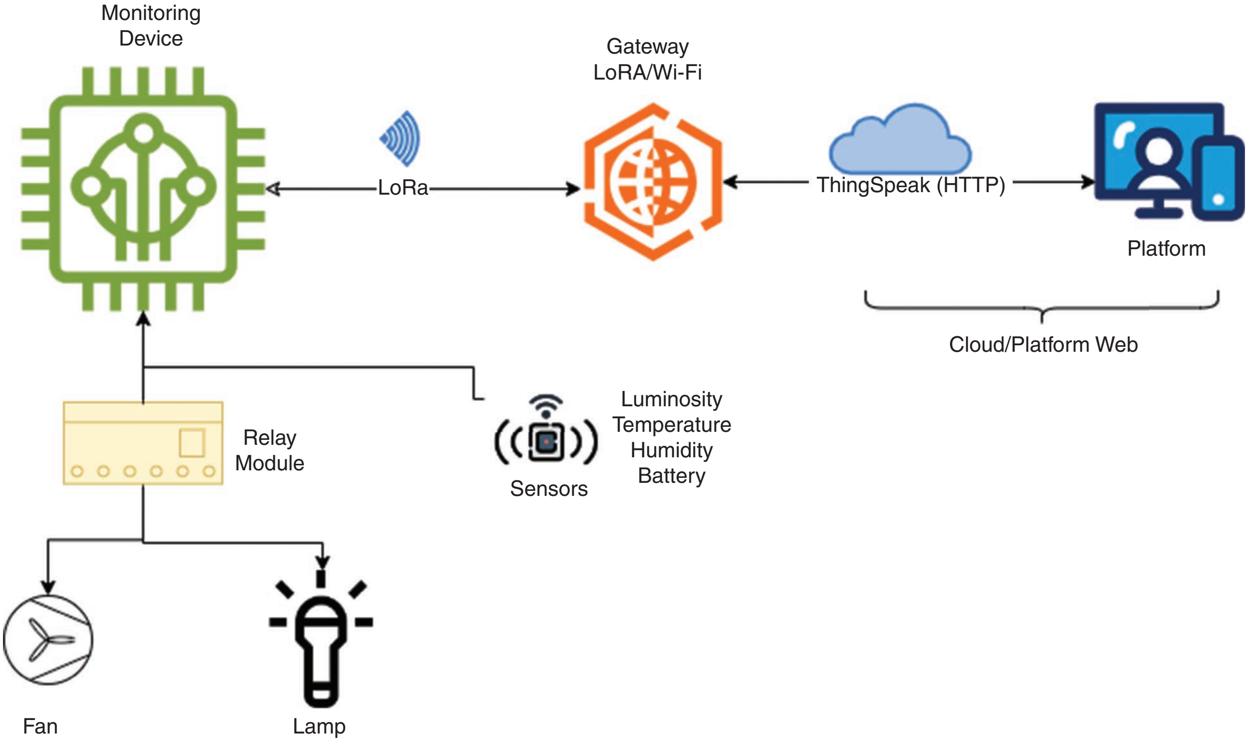

FIGURE 1. Design of the IoT-based system architecture; adapted from Lopes et al. 2021.[6]

and device battery levels. Built around the JARM ESP32 microcontroller—a cost-efficient platform equipped with integrated Wi-Fi and Bluetooth capabilities—the device includes a suite of sensors and communication modules. Specifically, the SHT20 sensor ensures accurate temperature and humidity readings, while a LoRa module (explained in the next paragraph) facilitates long-range data transmission. An SD card provides local data storage, ensuring redundancy in case of connectivity issues. To guarantee continuous operation, the device is designed with dual power sources: a dc plug and a battery holder, safeguarding functionality during power outages. The firmware, developed using Arduino IDE and C++, is compatible with a wide range of sensors and communication protocols and benefits from extensive community support, which simplifies both development and future expansion.

- *LoRa/Wi-Fi Gateway*: Given the frequent limitations in Wi-Fi coverage in farm environments, a LoRa/Wi-Fi Gateway bridges the Monitoring Device to the cloud. Also built on the JARM ESP32 platform, the gateway integrates both LoRa and Wi-Fi communication technologies. It receives data over long distances via LoRa from the Monitoring Device and transmits it via Wi-Fi to the ThingSpeak Cloud for further processing. This setup ensures reliable data transmission, even in areas distant from Wi-Fi access points, while maintaining the real-time availability of environmental data crucial for decision making.
- *ThingSpeak Cloud Platform*: The ThingSpeak Cloud serves as the system's data repository and analytics engine. As an open source IoT platform, it facilitates the collection, processing, and visualization of data transmitted from the farm. The platform supports standard communication protocols, such as HTTP and MQTT, making integration with various IoT devices straightforward. Real-time visualization of sensor data enables immediate insight into environmental conditions within the poultry house, allowing for rapid interventions when necessary to maintain optimal conditions for poultry health and productivity.
- *Custom Web Platform*: User interaction and data visualization are further enhanced through the development of a custom Web Platform. Constructed using JavaScript, HTML, Cascading Style Sheets, and WordPress plug-ins, the platform delivers a user-friendly interface displaying real-time sensor readings alongside control mechanisms for critical systems, such as fans and lighting. Users can set environmental thresholds (for example, temperature limits) and receive automated alerts when these thresholds are breached, enabling proactive environmental management. Additionally, the platform supports historical data visualization through graphs, which aid in trend analysis and informed decision making for long-term operational improvements.

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Automation and control

The system implements automation via a 5-V, four-channel relay module, currently utilizing two channels to control a fan and a lamp. The relay module operates in response to signals from the Monitoring Device, based on real-time environmental data. This automated control ensures optimal environmental conditions within the poultry house, reducing manual intervention and enhancing both animal welfare and operational efficiency.

Design philosophy: modular and independent operation

A key strength of the system is its modularity and independent operation, ensuring resilience against individual component failures. For example, the Monitoring Device continues to collect and store data locally even if the LoRa/Wi-Fi Gateway or Internet connection fails. This autonomy is critical for maintaining uninterrupted monitoring and control functions, particularly in remote or underresourced farming environments. By preventing cascading system failures, the design enhances reliability, a key requirement for agricultural applications.

Technological choices and scalability

The system's architecture is built around principles of cost-efficiency, reliability, and scalability. The use of the ESP32 board within the Arduino ecosystem ensures affordability without sacrificing flexibility or performance, supporting a wide array of sensors and communication protocols. LoRa technology is chosen for its low-power consumption and long-range capabilities, which are particularly beneficial in the context of geographically dispersed farm environments.

The integration of open source platforms, like ThingSpeak, combined with widely used web technologies for platform development, reduces both initial costs and the barriers to future scalability.

Study conduction and key results

The present study sought to evaluate the efficacy of a cost-effective IoT application specifically designed to optimize poultry farming through the automation of environmental monitoring and control. The experimental research was conducted at a poultry farm located in Iaciara, Goiás, Brazil, utilizing 20 one-day-old, properly vaccinated chicks. These chicks were evenly divided into two distinct groups: one group of 10 chicks housed in an IoT-assisted environment (the monitored group) and a control group of 10 chicks without the benefit of such automation. The region's tropical savanna climate, characterized by temperatures fluctuating between 18 °C and 34 °C, served as a suitable setting for assessing the IoT system's capability to sustain optimal environmental conditions for poultry rearing.

The experimental infrastructure comprised stalls situated within the farm's poultry house, each measuring 1.9 m by 1.65 m. These stalls were enclosed with a 1-in-thick mesh, shielded by tarpaulin to offer protection against excessive wind and cold. All stalls were uniformly outfitted with heating lamps, consistently operating to maintain an average ambient temperature of 31 °C, which is crucial for ensuring thermal comfort in the early stages of chick development (Figure 2).

In the monitored stall, supplementary equipment was integrated with the IoT system, including an additional heating lamp and a fan. The secondary heating lamp was triggered automatically when the temperature dropped below the desired range, while the fan was activated upon exceeding the thermal threshold. This IoT-driven apparatus provided real-time environmental data and made necessary adjustments autonomously, thus minimizing the need for manual interventions and the constant physical presence of farm personnel.

The experiment ran from 23 August to 20 September 2022, during which time both groups of chicks were fed and watered twice daily for 28 consecutive days, in the early morning and late afternoon, ensuring nutritional parity. Oak wood bedding was utilized uniformly across all stalls to absorb moisture, manure, and feathers, and it was replaced on a weekly basis. The used bedding material was collected in labeled plastic bags, and we carefully documented the collection dates and corresponding stall information for future reference.

Notably, the monitoring procedures differed significantly between the groups. The control group was subjected to routine physical checks approximately four to six times daily to identify signs of thermal or environmental stress. Conversely, the monitored group benefited from continuous oversight through the IoT system, which provided automated environmental adjustments without the need for direct human intervention.

Upon conclusion of the experiment, the chickens were weighed to measure growth performance. The results were statistically significant: the IoT-monitored group achieved an average weight increase 25% greater than that of the control group. A p value of 0.045 affirmed the statistical significance of the difference, suggesting that the IoT-based system had a demonstrably positive effect on weight gain.

The results of this study indicate that the IoT-based environmental monitoring system was successful in maintaining optimal conditions, leading to enhanced growth rates in the monitored group. Automated environmental adjustments contributed to a healthier, less stressful environment, which in turn facilitated better feed conversion efficiency. Furthermore, the system's automation significantly reduced the need for manual monitoring, offering substantial labor savings and operational efficiency, which is

The use of the ESP32 board within the Arduino ecosystem ensures affordability without sacrificing flexibility or performance.

FIGURE 2. A photograph of the real environment with the system deployed.

especially advantageous for small-scale poultry producers.

The integration of automated environmental control systems, when combined with the use of poultry breeds possessing high productivity potential, appears to generate synergistic benefits for overall production. In this study, the monitored chickens not only exhibited accelerated growth but also likely enjoyed superior health outcomes because of the stable environmental conditions maintained by the IoT system. Although the magnitude of improvement may vary across different growth phases and poultry species, the observed positive trend underscores the potential for enhancing poultry production through IoT-driven automation.

However, while the study demonstrates promising results, several avenues for future research emerge. First, further experimentation with larger sample sizes and extended monitoring periods would provide more robust data to generalize these findings across different poultry breeds and growth stages. Additionally, future studies could explore the adaptability of the IoT system to diverse climatic conditions as well as its effectiveness in managing other critical environmental factors, such as humidity, air quality, and lighting, which also impact poultry health and productivity.

Moreover, the integration of machine learning algorithms into the IoT system could enable predictive adjustments based on historical data, further improving environmental management by anticipating climate fluctuations or animal behavior. Research could also investigate the cost–benefit analysis of IoT implementation on various scales of poultry farming, offering insights into the economic viability for both small-scale and large-scale producers. **C**

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