DEVELOPMENT OF AN INTELLIGENT EGG INCUBATOR SYSTEM BASED ON ARDUINO

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Abstract. Artificial incubation systems play a crucial role in modern poultry farming by ensuring stable environmental conditions for embryo development. This study presents the design and implementation of an intelligent egg incubator based on the Arduino microcontroller platform integrated with environmental sensors and automated control mechanisms. The proposed system monitors temperature and humidity in real time and automatically regulates heating, ventilation, humidity generation, and egg turning processes. A real-time clock module ensures scheduled egg rotation, while IoT integration enables remote monitoring. Experimental results demonstrate improved environmental stability and increased hatchability compared to manual incubation methods. The developed system provides a low-cost, energy-efficient, and scalable solution.

Keywords: Smart incubator, Arduino, IoT, temperature control, humidity regulation, intelligent systems.

I. Introduction

Poultry production remains one of the fastest-growing sectors of agriculture worldwide. Artificial incubation technologies are widely used to increase productivity and reduce dependence on natural brooding processes. Successful embryo development requires strict control of environmental parameters, primarily temperature, humidity, ventilation, and egg turning frequency [1]. Traditional incubators often rely on manual monitoring, which leads to fluctuations in environmental conditions and reduced hatch rates. With the development of embedded systems and low-cost microcontrollers, intelligent automation has become accessible for agricultural applications [2]. The objective of this research is to design and evaluate a smart egg incubator capable of autonomous environmental control and remote monitoring.

II. Related Work

Recent studies have explored automated incubation systems using microcontrollers and embedded platforms. Sensor-based incubators employing temperature and humidity monitoring have demonstrated improved consistency in incubation environments. IoT-enabled agricultural systems further enhance monitoring capabilities through remote data access [3].

Previous research mainly focuses on temperature regulation, while integrated control involving humidity management, egg rotation scheduling, and intelligent alerts remains limited. This study addresses these limitations by proposing a fully automated modular architecture.

III. System Architecture

The proposed system consists of sensing, control, and actuation layers. Hardware components include Arduino Uno, DHT22 sensor, relay-controlled heating system, ultrasonic humidifier, servo motor for egg rotation, ventilation fan, RTC DS3231 timing module, and LCD interface [4]. Sensor data are continuously processed by the microcontroller, which regulates environmental parameters according to predefined thresholds (image 1.).
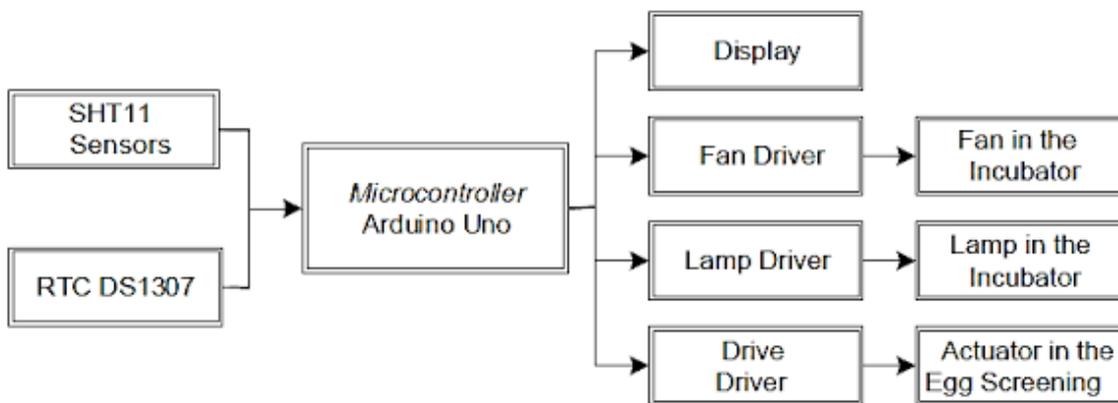

Image 1. Incubation Control Scheme

The proposed system consists of sensing, control, and actuation layers (Image 2).

Hardware Components:

- Arduino Uno microcontroller
- DHT22 temperature and humidity sensor
- Relay-controlled heating system
- Ultrasonic humidifier module
- Servo motor for egg rotation
- Ventilation fan
- RTC DS3231 timing module
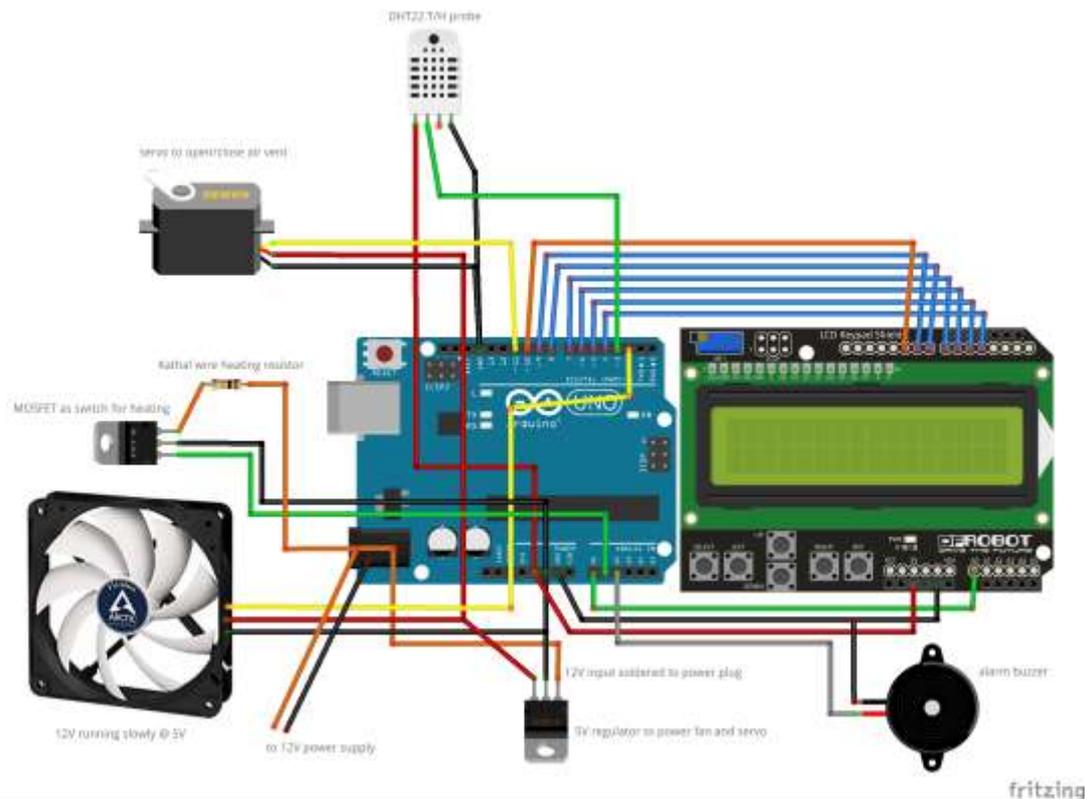- LCD monitoring interface

Image 2. Sensor connection diagram on Arduino device

Control Principle. Sensor data are continuously collected and processed by the microcontroller. Control decisions are made according to predefined incubation thresholds.

Control logic:

- Temperature < threshold → heater ON
- Humidity < threshold → humidifier ON
- Scheduled intervals → egg rotation
- Abnormal conditions → alarm activation

IV. Mathematical Model of Environmental Control

Temperature regulation is defined by the error between desired and measured temperature. A binary control signal activates heating when the temperature falls below the set value. Humidity regulation follows a similar mechanism. Future improvements may include PID or fuzzy logic controllers to reduce oscillations and improve stability [5].

Temperature regulation can be expressed as:

$$E_T = T_{set} - T_{measured}$$

Humidity error:

$$E_H = H_{set} - H_{measured}$$

Control decision:

$$Control = \begin{cases} ON, & Error > Threshold \\ OFF, & otherwise \end{cases}$$

Humidity regulation follows a similar binary control mechanism.

Future improvements may incorporate PID or fuzzy logic controllers to minimize oscillations.

V. Software Implementation

The system software was developed using Arduino IDE in C/C++. The program performs sensor data acquisition, threshold comparison, actuator control, display updates, scheduled egg turning, and alarm monitoring. The RTC module ensures accurate timing independent of power interruptions.

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– Scheduled egg turning
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VI. Experimental Results

Experiments were conducted over a full 21-day incubation cycle using chicken eggs. The proposed system achieved temperature deviation of ±0.3°C and significantly improved humidity stability. Hatchability increased from approximately 72% in manual systems to 91% using the automated solution, while human intervention requirements were minimized.

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Parameter	Manual Incubator	Proposed System
Temperature deviation	±1.5°C	±0.3°C
Humidity stability	Medium	High
Hatchability rate	72%	91%
Human intervention	High	Minimal

The proposed system significantly improved environmental stability and hatch success.

Discussion

The results confirm that automated environmental regulation improves embryo survival conditions. The integration of real-time monitoring reduces human error and enhances operational efficiency. Additionally, the system demonstrates affordability compared to commercial incubators.

Limitations include sensor calibration sensitivity and dependence on electrical power stability.

Conclusion

This paper presented an intelligent egg incubator system based on Arduino and IoT technologies. The developed prototype successfully maintained optimal incubation conditions and improved hatchability rates. The system is scalable, cost-effective, and suitable for small-scale poultry farms and educational research applications.

References

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