Design and Development of an Automated Smart Egg Incubation System

Improving Hatchability through Automated Temperature and Humidity Control

1st Abdul-Rehman Awan
Department of Mechatronics and Biomedical
Engineering Air University
Islamabad, Pakistan
231779@students.au.edu.pk

2nd Rehan Nasir
Department of Mechatronics and Biomedical
Engineering Air University
Islamabad, Pakistan
231830@students.au.edu.pk

3rd Abad Ali Khan
Department of Mechatronics and Biomedical
Engineering Air University
Islamabad, Pakistan
231785@students.au.edu.pk

Abstract— **Egg incubation requires proper control of temperature and humidity for successful hatching. In traditional incubators these conditions are usually adjusted manually which increases human effort and can result in poor and inconsistent hatch rates. This paper presents the design and development of a low-cost Smart Incubator System which can automatically control the main environmental conditions for eggs in incubator. In traditional setups, users may manually check temperature and humidity which required human effort and often causes lower hatch rates. To solve this problem, this proposed system uses two control loops to maintain both temperature and humidity. Temperature is controlled using a thermostat temperature controller that operates a 12W bulb as heating element and a 12V DC fan to keep the temperature stable around 37.5°C in the incubator. Humidity control is performed by an Arduino Uno microcontroller. A temperature and humidity sensor with display helps to view the current humidity and temperature. A soil moisture sensor is used to check the water level and a 5V pump is activated through a 1-channel relay to maintain the humidity. The system was tested for maximum 24 hours and it can successfully maintained its temperature and humidity without any manual adjustment. The incubator is built with commonly available components costing around 4,250 PKR. The overall design is easy to use and suitable for small poultry farms and educational projects.**
Keywords: Smart Incubator System, Temperature Control, Humidity Control, Arduino Uno, Thermostat Controller, Soil Moisture Sensor, Relay Module.

I. INTRODUCTION

Incubation is the process of keeping the fertilized eggs warm in order to allow proper development of the embryo into a chick. It may either be natural or artificial. In natural incubation the bird provides the required conditions for the relatively few eggs she lays by sitting on the eggs intermittently until they hatch in an open space The need for artificial incubator is to generally increase hatchability of eggs which leads to the improvement and increase in the production of chicks and eggs for human consumption and the economic market in this present age of information technology systems are mostly achieved through mechatronic means with

emphasis on soft control, this is mostly achieved by the use of programmed microcontrollers. The main aim of this work is to model design and develop an incubator system which is cost efficient and capable of incubating egg within the temperature range of 37.5 degree [1, 2]. This paper proposed the design and implementation of a Smart Incubator System integrating a thermostat temperature-controlled heating mechanism with a 12W bulb for heat and a 12W fan for temperature regulation and airflow distribution Moreover, the incubator has an Arduino based automatic water supply system with the help of a soil moisture sensor, 1-channel relay module, and 5V water pump to maintain humidity levels. Temperature and humidity sensor display is placed in it to check the level of humidity. The main objective of this project is to reduce human effort by introducing automation. To enhance the system. The system uses an Arduino Uno microcontroller to control the water pump [2]. When the water is reduced to the required level the Arduino sense it and automatically refills it. This automation makes the system reliable and user-friendly. This project combines a Smart Incubator System with an automated water refill feature controlled entirely by Arduino.

Kommey et al. [1] give the idea of a low-cost smart egg incubator capable of automatically controlling temperature and humidity. This system demonstrated reliable environmental regulation using simple and affordable low cost components.

Ariffin et al. [2] developed an IoT-based chicken egg incubator that uses sensors and automation to stabilize the incubator environment. Their approach enables real-time monitoring and control, but reliance on internet connectivity increases system complexity and cost, which may limit its use in small-scale poultry farms.

Islam Juel and Ahmed [3] presented a smart auto-balanced incubation system designed to maintain stable internal conditions during the hatching process. Although the system improves environmental stability, its control mechanism is

GuzmanZabala and Castro-Martin [4] proposed a smart semi industrial egg incubator with remote monitoring using LoRa technology. The system provides long range communication and reliable monitoring

Ali and Saleh [5] described the implementation of a semi-industrial smart egg incubator equipped with long-range remote monitoring capabilities. The system is suitable for large-scale applications

Chidiebere et al [6] create an enhanced nuero fuzzy based smart incubator system capable of automatically controlling heating humidity and temperature without manual intervention.

Bhuiyan et al [7] presented an IoT enabled smart egg incubator with remote monitoring and real time control features. The system enhances user accessibility and supervision but its dependence on continuous internet connectivity increases operational complexity.

Izadeen and Kocher [8] provided a comprehensive review of micro controller based smart egg incubator technologies and automation methods. Their study highlighted the effectiveness of embedded systems in incubation.

Che Mat Haris [9] focused on the design of a smart egg incubator system emphasizing automatic temperature regulation.While effective for thermal control the system offers limited humidity management and monitoring features.

Peprah et al. [10] proposed a smart solar powered incubator integrated with GSM/IoT communication for temperature regulation. Although environmentally sustainable the system's performance is highly dependent on solar availability and increases total cost.

Kumar et al. [11] investigated temperature and humidification control mechanisms in a solar-assisted egg incubator. Their results demonstrated stable environmental control

Elgeme et al. [12] proposed the development and control of a smart incubator system for premature babies using digital sensors and micro controller based control with remote monitoring. Although the system demonstrates precise environmental regulation, its medical-grade design increases complexity and cost compared to poultry incubators. The work presented in [13] focused on the development and temperature control of a smart egg incubator for quail birds using micro controller based control. While effective for hatching the system mainly emphasizes temperature regulation and provides limited discussion on automated humidity management.

Ohemu et al. [14] introduced a remotely monitored iot based smart egg incubator with automated temperature and humidity control. The system improves incubation reliability however, its Embedded solution, processing signals from speed sensors to maintain a steady speed set by the rider in real-time.

Sanjaya et al. [15] proposed an IOT driven smart incubator for quail eggs using a human-centered design approach. The system achieved effective automatic control, but increased design complexity and network dependency raise implementation costs. The study in [16] further extended human-centered design principles to an IoT-based quail egg incubator control system. Although user interaction was improved, the system still relies heavily on continuous internet connectivity.

Salah Uddin et al. [17] developed a portable baby incubator with smartphone-based monitoring. The system enhances portability and   remote supervision However its application is   limited to neonatal healthcare rather than agricultural incubation.

Mutaqim et al. [18] presented an IoT-based egg incubator powered by solar energy for sustainable farming with environmentally friendly the systems performance is affected by solar availability and weather conditions.

Abbasi et al.[19] discussed advancements in IoT enabled infant incubators to improve neonatal monitoring and care. Despite high accuracy and reliability such systems are not economically feasible for small scale poultry applications.

Mariapushpum et al. [20] designed an intelligent neonatal incubator integrating automation and monitoring technologies. Although effective for healthcare environments the system is costly compared to poultry incubator solutions.

II. SYSTEM ARCHITECTURE METHODOLOGY

The smart incubator is a device that maintain the optimal environmental conditions for growth. It uses sensors and motors to control automatically the internal temperature and humidity.
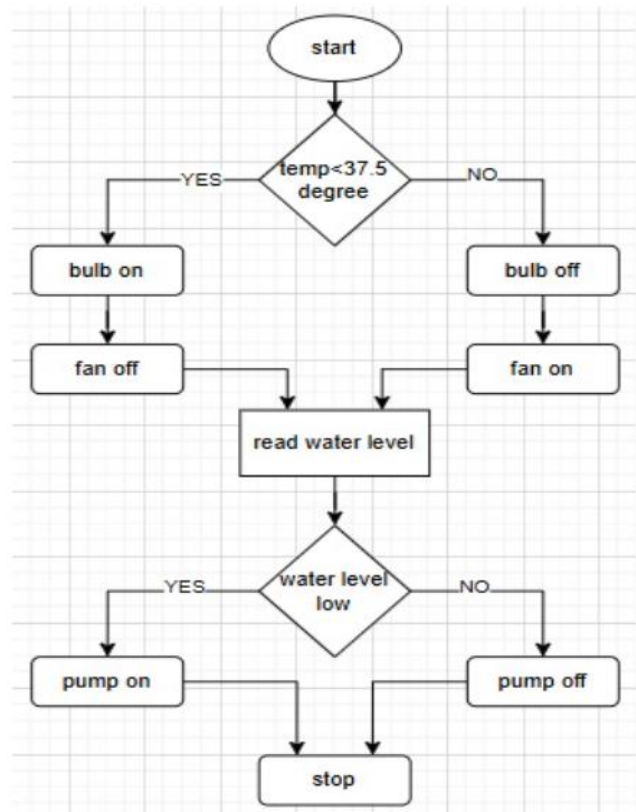

Fig. 1. System Flowchart

After these steps the process ends and the system keeps repeating to maintain good conditions inside the Incubator.

MATERIALS AND METHODS

A. Components

This incubator is working with several components. Thermostat temperature controller is used to control our temperature to require limit. Temperature sensor that will measure the temperature in our smart incubator. Humidity sensor is used to measure the humidity and also this sensor measure the temperature and show it on the LCD. We used Arduino Uno to control the water level in the incubator. Pump of 5v that will maintain the level of the water through our tank. Soil moisturizer is used to indicate water level it will measure the level in the incubator bowl if it is getting low it will give message to our system and our relay will on and make pump to maintain the level again. A fan is use to maintain the temperature and humidity and distribute it air in whole incubator.
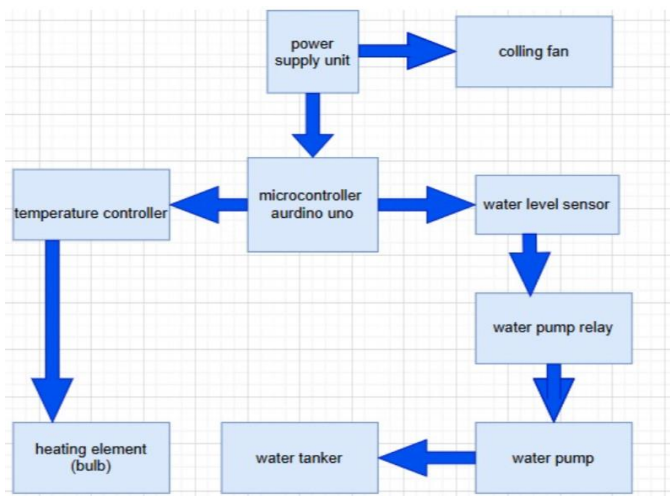

Figure 2 System Block Diagram

B. System Architecture

This flowchart shows how the incubator system works automatically. Thermostat starts reading the sensor values inside the incubator. . If the temperature is higher than 37.5°C. The system turns the bulb off. If the temperature is lower than 37.5°C it turns the bulb on to increase the heat [4].When the temperature is normal both the bulb and the fan stay on to keep the air warm and moving. At the same time this system checks the water level. If the water level is low the sensor sends this information to the Arduino. The Arduino then checks the information if the humidity needs more water [4]. As shown in Figure 3.
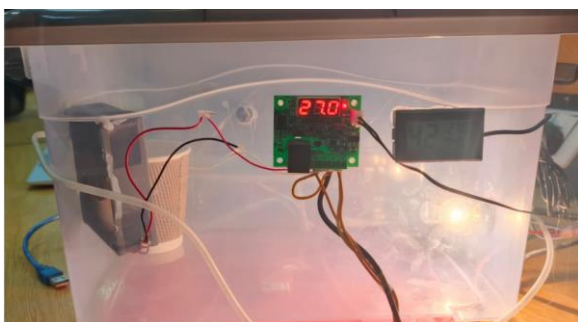

Figure 3 Project Architecture

It Switch the water pump on to refill the water and maintain the humidity. After these steps the process ends and the system keeps repeating to maintain good conditions

Inside the incubator.

III. ELECTRICAL DESIGN INTEGRATION

A. Proteus Circuit Design

The circuit was developed in the project to operate the automatic water refilling and environmental control system of the incubator. Figure 4 shows the complete PCB-based circuit used in the incubator system.
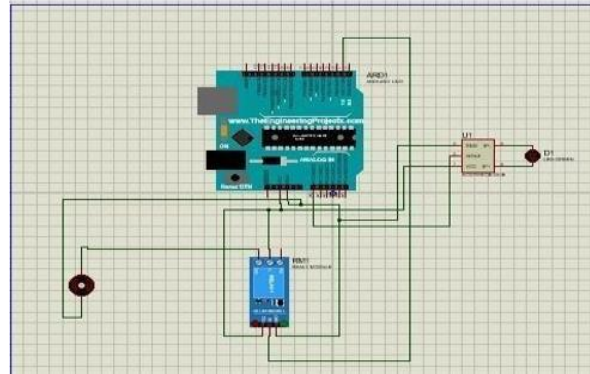

Figure 4 Circuit Diagram

The entire circuit of the Incubator, where 12 w Bulb of +ve terminal is connected with W1209 Thermostat terminal k1 and negative terminal of the bulb is connected with the battery 12 W DC fan connected with the negative and positive terminal of the battery. Where K0 and 12 V terminal of the thermostat is connected with positive of the battery and ground is connected with the negative and the fifth pin is for temperature sensor [6]. The sensor is placed at the center of the incubator to measure the temperature and humidity accurately .As shown in Figure 5 small water tank is added for humidity and the pump is positioned properly to supply water.

The temperature control system perform well during testing. When the temperature inside the incubator fell below the set point for

B. Electronics & wiring

Sensor pin is connected to the Arduino and relay is wired to another output pin. The fan and pump are powered with a 12V dc supply while the pump is controlled by the Arduino with help from the soil moisture sensor as shown in figure 5.
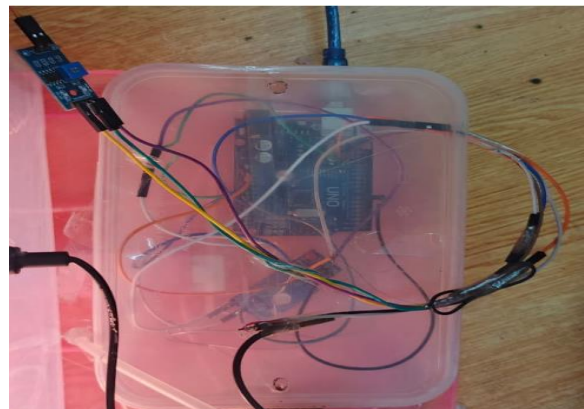

Figure 5 Connection with sensor and Arduino

All components share a common ground for safety purposes. The control algorithm manages temperature by turning the heating relay on. The set point minus the

The hysteresis value and turning it off when the temperature reaches the set point it plus the hysteresis [7, 8].This system displays the current temperature and humidity value. Calibration and testing include checking the heater performance measuring temperature distribution inside the box testing the humidification system to reach the desired humidity and running the incubator continuously for 24 hours to confirm behavior is stable or not. As shown in Figure 5.

IV. RESULTS

The Incubator System was successfully designed to maintain its temperature, humidity and water levels required for proper eggs incubation. This project reached the main objective for creating a fully automatic an incubation environment using sensors, motors, and a microcontroller. Each component was tested individually and then integrated to verify the complete operation of the system under real incubation conditions. The incubator hardware consists of a temperature and humidity sensor, bulb for heat and DC fan for air circulation while water pump and a soil moisturizer system connected with Arduino. Once assembled, the first stage of we test and check every module to be sure that there is no wiring issues or component faults were present. The temperature and humidity sensor provided the real-time readings which were continuously displayed on the display screen.

The temperature control system perform well during testing. When the temperature inside the incubator fell below the set point for example, below 37°C thermostat temperature control on the bulb to provide heat. When the temperature reached the upper safety limit around 38°C the heater automatically switched off. This automatic ON/OFF behavior successfully maintained the required incubation temperature of approximately 37.5°C which is critical for embryo development. Throughout the testing period the temperature remained stable. Humidity was regulated using a water pump and humidity sensor. When humidity dropped below the required level then Arduino will switch on the water refilling system to increase moisture inside the incubator. After reaching the set humidity value the pump automatically stopped. This feedback based control consistent moisture levels and preventing eggs from dehydration and supporting proper incubation.

DC fan played a vital role in distributing warm air inside this incubator. Without proper airflow and temperature can vary from one corner to the other. Testing represents that with the fan running the incubator maintained their internal temperature by improving hatchability and overall performance. All the results are shown below the Figure 3

In Smart Incubator System the water level indicator is implemented using a soil moisture sensor which functions as a water presence detector. Instead of using float sensors or metal probes or copper wires the soil moisture sensor provides a simple and effective way to measure whether water is available in the incubator's water or not. Soil moisture works on the principle of conductivity. Water conducts electricity better than air so the sensor measures the resistance between these two probes. When the probes are placed inside the water the sensor output changes allow the Arduino to determine whether the water level is high, medium, or low. We used this method in the incubator because it gives the incubator several advantages .Water never runs out because the system detects low levels. The incubator continuously regulates humidity.   [9]

V. CONCLUSION

The Incubator System proposed in this project worked well for keeping the best conditions for hatching eggs in the incubator.

It uses sensors, motors and a microcontroller to control temperature, humidity and water level automatically. This means people don't manually adjust things by hand as they do before. Every part of this project checks carefully and then combines together to make sure everything worked properly. Temperature and humidity sensors give them accurate readings so the Controller would able to change settings quickly if the conditions went out of the required limit. Bulb used as a heater and fan kept the temperature close to 37.5°C which is important for baby chicks to grow. The system turned the heater on and off when needed so the temperature stays well for eggs.

The humidity control also worked well. If the humidity went down the Arduino turned on the water pump to refill water for moisture. Once the water become full in the required glass the pump turned off automatically. This stopped too much or too little moisture which is bad for eggs. The system used a soil moisture sensor to check the water level which is cheaper and more reliable than old methods. The fan helped to spread warm air kills the cold spots inside the incubator. All together this project made a good environment for eggs to hatch. It receives feedback from sensors and automatic controls working well. The design is cheap and easy to use and can be improved with features like remote monitoring.

VI. REFERENCES

[1]   B. Kommey, D. Akudbilla, G. Doe, and C. Amponsah, "A low-cost smart egg-incubator," Sustainable Engineering and Innovation, vol. 4, pp. 22–33, Feb. 2022, doi: 10.37868/sei.v4i1.id152.

[2]   M. I. S. T. Ariffin, N. I. A. N. Amin, M. A. H. A. Abas, R. L. Jamil, and S. Z. Yusof, "Designing a Chicken Egg Incubator with IoT-Based Control," Asian Journal of Vocational Education And Humanities, vol. 6, no. 1, pp. 28–33, June 2025, doi: 10.53797/ajvah.v6i1.4.2025.

[3]   Md. T. Islam Juel and Md. S. Ahmed, "A Smart Auto-Balanced System for Incubation Process," in 2019 International Conference on Robotics,Electrical and Signal Processing Techniques (ICREST), Jan. 2019, pp. 564– 569. doi: 10.1109/ICREST.2019.8644295.

[4]   J.-V. Guzman-Zabala and A.-P. Castro-Martin, "Smart and Semi-industrial Egg Incubator with Remote Monitoring Using LoRa Technology," in Proceedings of the International Conference on Computer Science, Electronics and Industrial Engineering (CSEI 2023), M. V. Garcia, C. Gordón-Gallegos, A. Salazar-Ramírez, and C. Nuñez, Eds., Cham: Springer Nature Switzerland, 2024, pp. 522– 540. doi: 10.1007/978-3-031-70981- 4_35.

[5]   D. Ali and K. Saleh, "Implementation of Smart Eggs Incubator System," Sept. 2018, Accessed: Nov. 26, 2025. [Online].Available:ouargla.dz/jspui/handle/123456789/18967

[6]   M. E. Chidiebere, I. S. Francis, and N. Ikechukwu, "Design and Implementation of an Enhanced Neuro- Fuzzy- Based Smart System for Poultry Incubators," Communication In Physical Sciences, vol. 12, no. 5, pp. 1583– 1599, June 2025.

[7]   M. A. U. Bhuiyan et al., "IoT Enabled Smart Egg-incubator with Remote Monitoring and Control System," in NY, USA: Association for Computing Machinery, June 2025, pp. 107–114. doi: 10.1145/3723178.3723193.

[8]   G. Izadeen and I. Kocher, "SMART EGG INCUBATOR BASED ON MICROCONTROLLER: A REVIEW,"Academic Journal of Nawroz University, vol. 11, pp. 139–146, Nov. 2022, doi: 10.25007/ajnu.v11n4a1401.

[9] H. I. H. Che Mat Haris, "Smart Eggs Incubator System," International Journal of Simulation: Systems, Science & Technology, Jan. 2016, doi: 10.5013/IJSSST.a.17.41.35.

[10] F. Peprah, S. Gyamfi, M. Amo-Boateng, E. Buadi, and M. Obeng, "Design and construction of smart solar powered egg incubator based on GSM/IoT," Scientific African, vol. 17, p.e01326,

Sept. 2022, doi: 10.1016/j.sciaf.2022.e01326.

[11] P. kumar T, A. Kumar R, K. Antony, R. N U, S. Durai T, and S. S. Nair, "Temperature and humidification control studies on solar assisted egg incubator," Eng. Res. Express, vol. 7, no. 3, p. 035501, July 2025, doi: 10.1088/2631-8695/ade6cc

[12] N. A. Elgeme, S. Soued, A. A. Ehfida, and M. Y. Fattouh, "DEVELOPMENT AND CONTROL OF SMART INCUBATORSYSTEM   FOR PREMATURE BABIES," Malaysian Journal of Industrial Technology, vol. 8, no. 1, pp. 54– 63, Mar. 2024.

[13] Full-Paper DEVELOPMENT-AND- TEMPERATURE-CONTROL-OFSMART-EGG-
INCUBATOR.pdf."Accessed: Nov. 26, 2025. [Online]. Available:https://www.idpublications.org/wpcontent/uploads/201 6/02/Full-   Paper-DEVELOPMENT-ANDTEMPERATURE-CONTROL- OF-SMART-EGGINCUBATOR.pdf

[14] M. Ohemu, U. Umar, A. Edmund, and Z. Zuleihat, "Design and Implementation of a Remotely Monitored Smart Egg Incubator," Nov. 2021.

[15] W. S. M. Sanjaya et al., "The development of quail eggs smart incubator for hatching system based on microcontroller and Internet of Things (IoT)," in 2018 International Conference on Information and Communications Technology (ICOIACT), Mar.2018, pp. 407–411. doi: 10.1109/ICOIACT.2018.8350682.

[16] "Internet of thing and automatics control system on quail egg incubator using human-centered design method | AIP Conference Proceedings | AIP Publishing." Accessed: Nov. 22, 2025. [Online]. Available: https://pubs.aip.org/aip/acp/article-abstract/2499/1/050011/2827088/Internet-of-thing-and-automatics-Control system-on.