Development of Egg Hatcher with the Application of the Internet of Things (IoT)

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Abstract.
The integration of technological advances in Internet of Things (IoT) technology has revolutionized agricultural practices, especially in poultry farming. Traditional chicken farming and incubation methods that rely on human monitoring and control often result in unstable conditions that negatively impact chicken health and hatchability. Challenges include environmental factors such as temperature fluctuations and inadequate humidity control, which lead to health problems for chickens and reduced hatching success of hatching eggs. Additionally, reliance on manual intervention limits efficiency and scalability for small-scale farmers. To address these challenges, a prototype model was developed that uses IoT sensors to monitor the environment inside incubators. The hatching process used a temperature control system with heating and cooling elements to simulate natural conditions and improve hatching success rates. The lamp and fan are used in this project to provide the egg with the appropriate temperature and humidity. The temperature and humidity of this egg incubator will be detected by the DHT11 sensor and shown on the smartphone app Blynk. This method includes remote monitoring to ensure optimal conditions for poultry health and egg hatching. As a result, the average temperature range inside the incubator is from 37℃ to 38℃. When it becomes 39℃, the light bulb will be off while the relative humidity (RH) range is from 55% RH to 65% RH for optimal conditions. This project will become user-friendly for all small-scale farmers as it is easy to maintain.

Keywords: Poultry Farming; Internet of Things (IoT); Incubators; Temperature; Humidity;

1 Introduction

Brooding happens when a female bird sits on her eggs to keep them warm and help them hatch. Like a chicken, a broody hen often neglects food and water to incubate her eggs or even eggs from other birds [1]. This shows their natural nurturing behavior. However, natural incubation faces challenges such as predators and environmen-

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tal conditions, which have led to the use of artificial incubation. Predators and changing temperatures can lower hatchability, making artificial incubation necessary to sustain poultry populations [2]. Agriculture is crucial for national stability and food security, significantly impacting the economy [2],[3]. From 1995 to 2015, global livestock production grew from 205 million to 319 million tons. The rising population and meat consumption are expected to double chicken meat production by 2020–2022 [2]. In Malaysia, the annual consumption per person is 370 eggs and 49.30 kg of chicken, with over 3000 chicken farms supporting this demand [4]. Educating the next generation in agriculture is essential [5]. Developing countries focus on increasing agricultural productivity as the demand for chicken and eggs grows, leading to more poultry waste [6],[7]. Artificial incubators can imitate a hen's broody state, enhancing egg production and creating ideal hatching conditions [8]. Traditional poultry farming is labor-intensive, involving manual tasks like feeding, cleaning, and lighting, which can lead to human errors and inconsistent incubation conditions [9],[10]. This manual approach can also stress farmers and hinder effective farm management. Adopting IoT and new technologies in agriculture allows for artificial incubation, improving hatching efficiency by precisely controlling temperature and humidity [11][12]. This project aims to provide poultry farmers with an automated monitoring system that reduces manual oversight and increases hatching success rates. Using sensors, the system keeps optimal hatching conditions by monitoring temperature, humidity, and egg turning. A microcontroller adjusts these conditions, activating bulbs and fans as needed. The incubation lasts about 20 days before the eggs move to the incubator [13],[14]. Integration with the Blynk app allows farmers to receive real-time alerts and monitor conditions remotely, supporting sustainable agriculture and aligning with the Sustainable Development Goals (SDGs) [15].

2 Methodology

The methodology is a framework for how the product can be successfully manufactured. Egg-hatching incubators involve a mechanical engineering design process and circuit and coding generation. The entire process, from brainstorming ideas, Phase I: System Generation, Phase II: Prototype Development, Phase III: Testing, and Phase IV: Data Collection, to creating the finished prototype with optimal conditions and functionalities.

2.1 Phase I: System Generation

System generation explains how the overall system works, including the flowchart and the circuit diagram that displays the system's components. Figure 1 depicts the operational system for the IoT prototype of the egg hatcher. It guides step by step to ensure the users become more knowledgeable about the system. It also shows the significant changes that improved chicken farming by employing intelligent systems, which were automated systems and real-time monitoring that ensured the eggs had the optimal conditions for hatching. The flowchart was constructed technically from data gathered throughout relevant research studies.

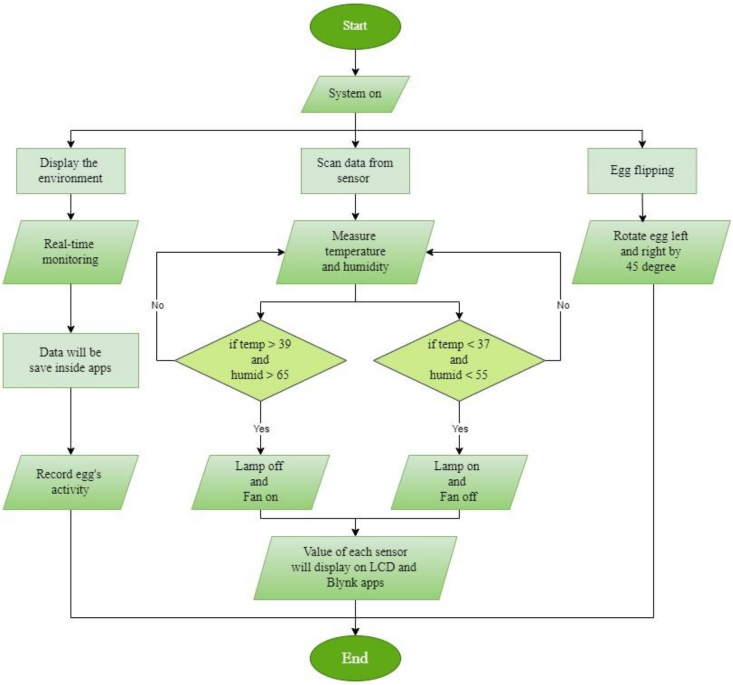


Fig. 1. Phase I - System flowchart

The system program started by turning on the power supply, and the LCD will display the environmental conditions. The main operation comes from the DHT11 sensor, which technically provides data to measure the temperature and humidity inside the incubator. When the temperature becomes 39°C and humidity rises to 65%, the lamp is turned off to cool the inside incubator while the fan is activated to decrease the humidity. Conversely, if the temperature falls to 37°C and moisture drops below 55%, the lamp is turned on, and the fan will be deactivated to raise the humidity levels. This integrated setup extends its reach to a Blynk application, facilitating remote access and control of the incubation environment. There are two additional outputs: the first one is a turning mechanism, and the second is a real-time monitoring system that can increase the hatching success rate. For a turning mechanism, egg-turner trays were used to rotate left and right by 45 degrees for optimal conditions of embryo development. Regular turning will prevent the embryo from sticking to the eggshell membrane and help distribute the heat evenly throughout the eggs. The mini camera was utilized to capture real-time videos to monitor the environment inside the incubator. The visualization will appear inside an application called 365Cam.

2.1.1 Development of the system

To provide the optimal conditions for the well-being of the chicken eggs before they hatch, developing an intelligence system to monitor them requires research and development. The prototype system integrates several main components that will be fixed together to become a complete control and monitoring system. It technically consists of two main parts: the software running the system and the hardware designing the final product.

Figure 2(a) below shows the main components to build the prototype of the egg hatcher. In contrast, Figure 2(b) shows a complete wiring diagram for the prototype egg hatcher that connects the main components, which was very important for the project operation system. The system has ESP32 (1) connected to the ESP32 shield expansion board (2), which serves as a microcontroller and the central control unit. The sensor that measures temperature and humidity inside the incubator, one of the leading data collections, is called DHT11 (3). Components are electrical and receive voltage through an adapter (4) that supplies power. A 4-channel 5v relay module (5) was used to control high voltage or energy, such as a fan, incandescent lamp, and egg-turning tray. The power supply was safely connected through a DC jack (6). I2C LCD (7) was used to display the temperature and humidity conditions in real-time data so the owner could monitor the incubator conditions regularly. 5V fan (8) was used for ventilation and temperature regulation, while an incandescent lamp (9) provided heat inside the incubator. For the additional output, an egg turner tray (10) was connected to eggs put above it and turned 45 degrees at regular intervals, which will indirectly mimic the natural hatching process. All of these are connected using jumper wires to form a functional circuit for this project.

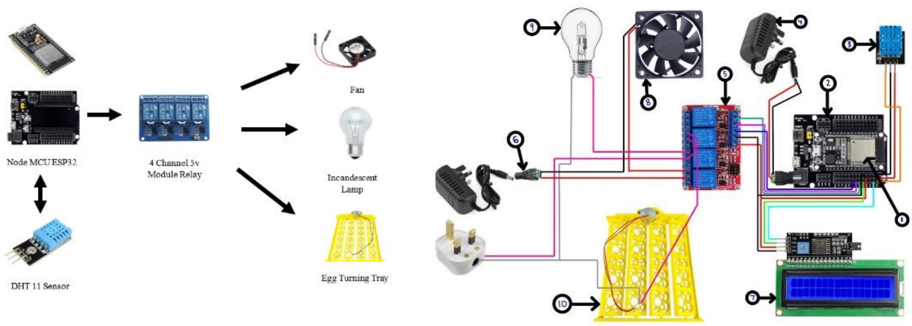
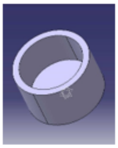
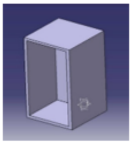
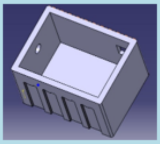


Fig. 2(a). Controller system using ESP32 as microcontroller, **Fig.2(b).** Circuit of prototype egg hatcher

2.2 Phase II: Prototype Development

Three conceptual designs for the prototype of the egg hatcher were created, focusing on shape, material, size, and weight with the primary aim of simplicity, user-friendliness, and low weight. Table 1 presents the evaluation of three initial conceptual designs for the prototype. However, based on a comprehensive analysis, Option 4, which came from a combination of the best features of the three initial designs, was selected as the final design as shown in Table 1.

Table 1. Conceptual design for general IoT of egg hatcher

Criteria	Option 1	Option 2	Option 3
Shape			
Material	Plywood	Polystyrene Foam	Acrylonitrile Butadiene Styrene
Size	Medium = 487 X 367 X 310mm	Small = 430 X 308 X 321mm	Big = 620 X 495 X 362mm
Sensor	Humidity sensor	Temperature sensor	Temperature & humidity sensor
Camera Monitoring	One unit	Zero unit	Two unit
Weight	3Kg	1Kg	5Kg

Option 4

After completing the conceptual design, the Pugh method will be utilized to evaluate the selected criteria, as shown in Table 2. Based on the morphological chart before, three initial options, with one coming from a combination of the best features of the three initial designs for designing a prototype egg hatcher, were compared with a variety of criteria, with each of them assigned a weight based on its importance that determined the successful outcome. The final score will be calculated by multiplying each description by its respective weight to determine the best choice for the prototype of the egg hatcher. Option 4 emerged as the best choice, with the highest final score of 14, indicating its superior performance across most criteria compared to the other options.

Table 2. Pugh's method for conceptual design evaluation

Description		**Selected Option**				
Criteria	**Weight**	**Datum**	**Opt 1**	**Opt 2**	**Opt 3**	**Opt 4**
Cost	2	0	0	+	-	+
Material	1	0	-	+	0	+
Durability	2	0	0	+	+	+
Safety	3	0	-	+	0	+
Market	2	0	+	-	0	0
Reliability	3	0	-	0	-	0
Practically	2	0	0	+	0	+
Portability	1	0	-	+	0	+
Maintenance	2	0	-	0	+	+
Space Fit	1	0	+	-	0	+
Quantity +		0	3	11	4	14
Quantity 0		19	6	5	10	5
Quantity -		0	10	3	5	0
Final Score		0	-7	8	-1	14
Design to be Develop		-	NO	NO	NO	YES

Using Catia software, the finished design was successfully built, including the leading hardware inside the incubator. The hardware components and wiring system were successfully assembled. The elements are also positioned correctly to give optimal conditions for eggs when they start the process of hatching. Fig. 3(a) shows the assembly of the prototype egg hatcher in Catia with the main components positioned respectively. Meanwhile, Fig. 3(b) below displays prototype general measurements.

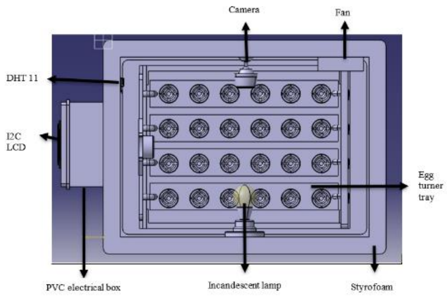


Fig. 3(a). Assembly of prototype egg hatcher

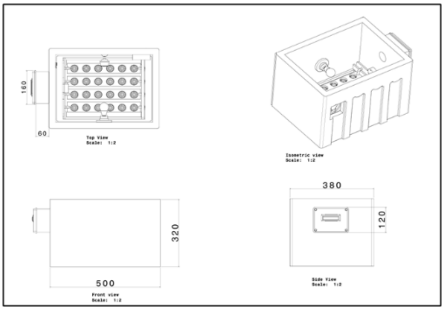


Fig. 3(b). Prototype general measurement

2.3 Phase III: Testing

In the testing phase, the project undergoes continuous testing to ensure that all components function correctly to achieve the desired output target, for example, to test whether the quantity of fan and light bulb is enough or not to get the temperature and humidity right for egg hatching, the egg tray can be turning right and left for 45 degrees or not and whether the camera is functioning for real-time monitoring. Adjustments and optimizations are made based on continuous testing to improve performance as the system desires. After several tests with successful data gathering, the eggs were put inside the incubator and stayed inside for approximately 21 days before hatching. Fig. 4(a) shows the actual condition of the system while Fig. 4(b) below shows the Blynk application, for the real-time data monitoring of temperature and humidity. The testing showed a temperature of 37℃ and humidity of 57% while the egg tray control was activated.

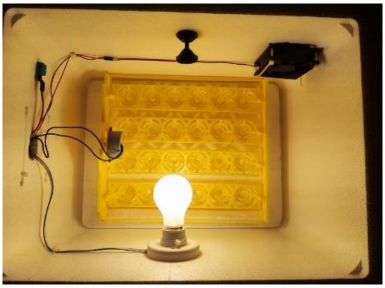


Fig. 4 (a). Overall system outputs

Fig. 4(b). Blynk application

2.4 Phase IV: Data Collection

The data collection phase commences after the testing is completed. This stage involves placing a batch of 8 chicken eggs inside the incubator and awaiting approximately 21 days for them to hatch into chicks. Subsequently, the percentage of successful hatching can be calculated based on this data. Following the proper process, temperature, humidity, and egg turning will be monitored throughout the day to prevent incidents like infertile eggs, which will lower the percentage of successful hatching.

3 Results and Analysis

Table 3 below provides the operational system specifically on temperature and humidity managed inside the prototype of the egg hatcher while focusing on the activation of the lamp and fan based on sensor readings. The first thing users need to do is turn on the power supply before the system runs. After that, the DHT11 sensor will start reading the conditions inside the incubator. When the temperature becomes 39°C and humidity rises to 65%, the lamp is turned off to cool the inside incubator while the fan is activated to decrease the humidity. Conversely, if the temperature falls to 37°C and moisture drops below 55%, the lamp is turned on, and the fan will be deactivated to raise the humidity levels. Simultaneously, the data is recorded in real time inside the Blynk application. If the power supply was cut off, the sensor would disconnect, and the lamp and fan would remain off, resulting in no data gathering inside the Blynk application.

Table 3. System operation for temperature and humidity sensor

Connection	Temperature and Humidity Sensor	Condition	Incandescent lamp	Fan	Blynk
Connected	ON	If temperature > 39°C and humidity > 65%	OFF	ON	Data recorded in real-time
		If temperature < 37°C and humidity < 55%	ON	OFF	
Disconnected			OFF		

Table 4 below shows an operation system on egg-turning conditions, one of the additional outputs. It happens by a mechanism inside the egg-turning tray. This tray has already been interconnected with an asynchronous motor 220V. This mechanism occurs when the user turns on the controller inside Blynk; the tray will turn 45° left and right. When the user turns off the controller inside the Blynk, the tray will stop where it stayed the last time. It was recommended that the eggs be turned at least 3 to 5 times at a 4 to 6-hour interval per day.

Table 4. System operation on egg-turning condition

Connection	Egg turning tray condition	Blynk Status
Connected	Turned 45° left and right	On
Disconnected	Stopped at where it stayed	Off

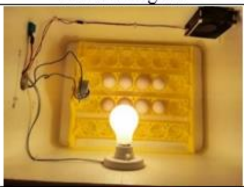
Table 5 below shows an operation system on the camera. When the camera is turned on, it will provide the user with videos in real-time of what is happening inside the incubator. This can prevent from opening the box to see what happens to the egg because it will disrupt the egg-hatching process.

Table 5. System operation on camera for real-time monitoring

Connection	Camera
Connected	Monitor the condition inside the application.
Disconnected	Off

Table 6 below shows a chronology of what generally happens between 21 days of process hatching. Typically, the incubator was preheated until it reached around 37°C - 38°C with a 55–65% humidity level.

Table 6. General chronology for approximately 21 days process hatching

Detailed Figure	Detailed Explanation
	The eight fresh eggs from the chicken farm were put on the tray. For 21 days, the eggs will stay there until they hatch to become the chicks. The tray turning mechanism was turned about four times daily until day 18.
	By day 7, candling eggs were done to check the development and viability of embryos. It can be seen that the blood vessels are visible from the eggs.
	By day 14, the embryo filled more of the egg's interior.
	The chicks break through their eggs through cracks, which they do naturally. Peeping sounds become more frequent and louder as the chick becomes more active. From 8 eggs, seven hatch to become chicks, while 1 becomes an infertile egg.

4 Conclusion

In summary, the primary concern of this research study was to provide a chicken incubator that many farmers or users can own. It will be user-friendly, easy to maintain, and cheaper than an industry incubator. The students have gained valuable insights and expertise in accomplishing the project's objectives. The IoT-driven system optimizes egg-hatching conditions by monitoring temperature and humidity and includes a real-time camera for continuous surveillance. It features a programmed egg-turning mechanism that gently tilts the eggs 45° left using asynchronous motor. This intelligent system, integrated with the Blynk app, simplifies egg monitoring for farmers, eliminating the need for manual checks. Even when off-site, farmers can remotely oversee the egg incubation process, showcasing the convenience offered by this technological innovation. The successful implementation of this IoT-based system exemplifies how technology can revolutionize traditional practices, enhancing productivity and quality in the egg incubation domain while providing solutions to meet industry-specific needs. The total cost of the project if the innovation project can be commercialized are around RM 250 which very reasonable price. This project serves as a testament to the transformative potential of innovation and technology in revolutionizing practices within the agriculture sector.

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Disclosure of Interests.
The authors declare that there are no conflicts of interest regarding the publication of this paper.

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