An Automated Egg Incubator with Raspberry Pi-Based Camera Assisted Candling and Maturity Detection using Convolutional Neural Network for *Balut* and *Penoy* Production

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***Abstract* – This study focuses on developing a semi-automated egg incubator with camera assisted candler for egg maturity detection of *Balut* and *Penoy* production. A four-layer chamber installed with a heater, fan, and DHT11 sensors that are connected to a Raspberry Pi 4 to observe and maintain the optimal parameters inside the incubator. Trays with built-in candlers made from fluorescent bulbs are placed per layer with a capacity of 24 eggs positioned on rollers that is programmed to drive every 8 hours for 5 minutes for the egg turning which is essential in incubating eggs. Cameras are installed to capture the images of the candled eggs on their 1st, 10th, and 18 th day. The images will then go through image processing with the use of Convolutional Neural Network (CNN) that is programmed using python language. The CNN will be trained to determine the distinct features of eggs such as the black spot, nerves, and embryo to recognize their age and classification. The result will be shown on a monitor with a user-friendly GUI which will help the vendor to determine the condition and maturity of the eggs inside the incubator.**

Keywords— Egg Incubator, Raspberry Pi, Camera Assisted Candling, Maturity Detection, CNN, Balut, Penoy.

I. INTRODUCTION

The Philippines is known for its popular exotic delicacy called *balut* and *penoy*. It is a boiled fertilized developing egg embryo that is at least 18 days old and is commonly sold by many street vendors in the country. Traditionally, eggs are incubated with the optimal parameters for it to develop properly but as the modern technology grows, artificial incubators are made to sustain more efficient environment for eggs. The only problem in the *balutan* industry is that candling process of eggs takes too long and incubators often produces *abnoy* which is not profitable.

Incubation stimulates embryonic development which is essential in the process of hatching an egg. For eggs to be hatched smoothly and prevent it from dying, there are many factors to consider along the process. Several studies exhibited that the factors affecting the incubation process are namely the following: temperature, humidity, ventilation and egg turning [1]. An artificial incubator should be able to stimulate and meet the optimum environmental conditions. One reason why egg don't hatch is because of overheating and underheating, since temperature is critical for the speed of their metabolic rate. Lack of moisture and turning is necessary because it can lead the chick to stick to the shell
[2]. The advised parameters for incubating duck and chicken eggs are 100F in temperature, 85-86 and 85-87 humidity, respectively. One more recommendation is to stop the turning process and open the vent after the 25th day for duck eggs and after 18th day for chicken eggs [1]. The demand of artificial incubator is for increasing the quality of eggs for the improvement of production for human consumption and economic market. In today's technology, control and automation of devices are accomplished using various techniques in electronics [3].

Candling is a way to sight the yolk, white, and the air cell of an egg. It is also a way to observe the germ development, blood spots, bloody white and the meat spots. Another purpose of this is to determine whether an egg is fertile or infertile depending on the development of the embryo. It works by placing the egg on a high-powered flashlight [4].

Convolutional Neural Network is a type of an artificial neural network that is powerful method for image processing and recognition. It implements descriptive and generative tasks of deep learning. The presence of human-like neurons enable it to produce accurate results in testing subjects [5]. As an example, a study entitled "Convolutional Neural Network for Industrial Egg Classification" used CNN for image classifying. They used 2000 egg images to train the CNN, giving the result of the project's accuracy for the 89,000 test subjects is 92.3% [6].

This study aims to develop a semi-automated artificial incubator that controls the parameters inside the chamber and the camera-assisted candling process for maturity detection to produce high quality eggs for the economic market of *balut* and *penoy* production.

I. METHODOLOGY

A. Block Diagram

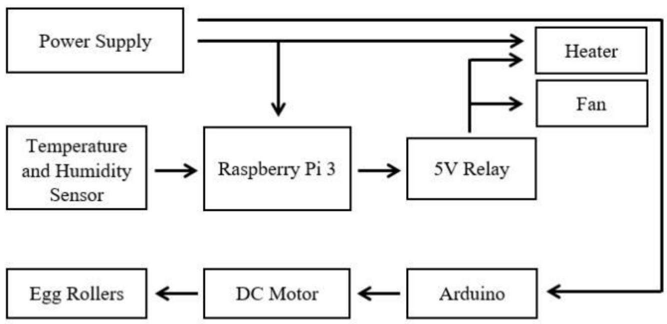

Fig. 1 System's Block Diagram

Figure 1 shows the block diagram of the incubation system. Here, the Raspberry Pi 4's objective is to automatically detect and regulate the temperature along with the humidity inside the incubator. By feeding the inputs in the microcomputer, the Raspberry Pi 4 will then analyze the given data and will trigger the relay that will make the heater and fan regulate the parameters depending on the readings. An Arduino powered by the 12V power supply is connected to a DC motor which drives the egg rollers for the egg turning.

B. Hardware Development

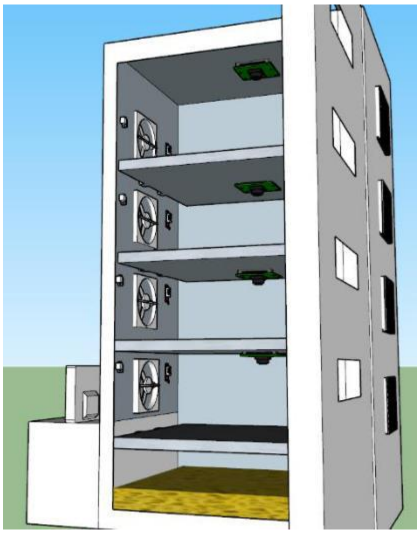

Fig. 2 Prototype Design

Figure 2 shows the hardware design of the incubator. The machine will have a height of 6ft, length of 4ft, and width of 3ft. Each layer consists of a fan visible on the left side and heater on the right side. It also consists of four DHT11 which serves as the temperature and humidity sensors that were located on the left and right side. Two at the front, and the other two is at the back side of every layer which signifies the temperature and humidity regulation on the four quadrants of each layer. The camera is located on top of every layer at exactly 19 inches distant from the tray. The box behind the incubator is where the power supply and other wirings located.

C. Software Development

Python was used in implementing the convolutional neural network which is needed to perform the maturity detection of the egg. The candling process was done in the Raspberry Pi 4 where the maturity detection was depicted through a user-friendly GUI for an easy implementation of the program. Raspberry Pi 4 was also used to automatically regulate the temperature and humidity inside the incubator. The egg rollers were programmed in an Arduino Uno to perform egg turning for every 8 hours.

- **Temperature and Humidity Control**

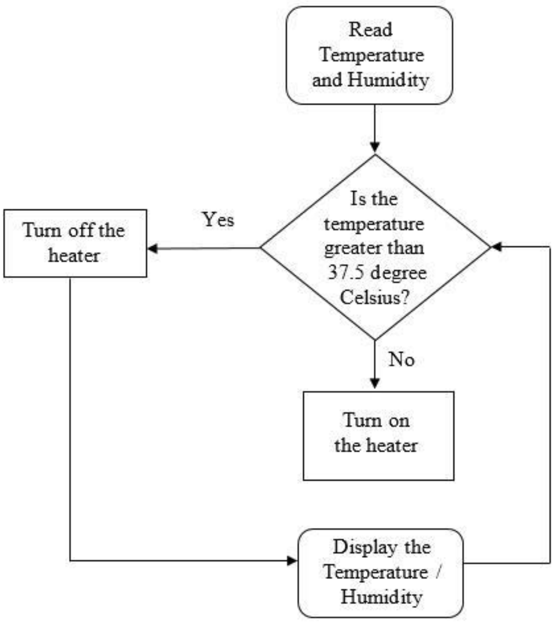

Fig. 3 Temperature and Humidity Control Flowchart

Figure 3 shows the process of automatically controlling the temperature and humidity. First, the humidity and temperatures will be detected by the sensors. If the temperature reading is higher than 37.5, the heater will be turned off but if the reading is below the set temperature, the heater will be turned on. Every reading will be displayed on the screen to ensure that the incubator will maintain the ideal temperature and humidity and for the user’s knowledge whether the parameter regulation is performing well.

- **Egg Turning Control Program**

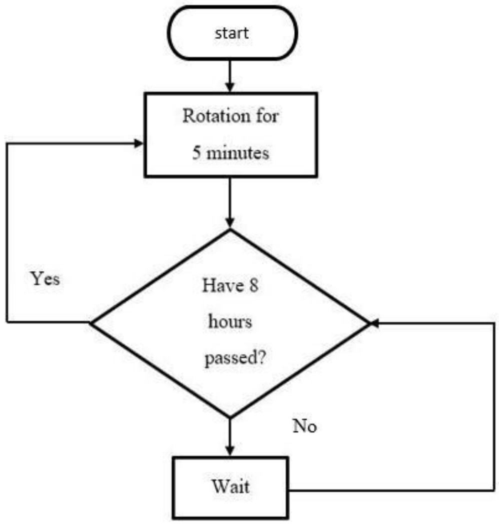

Fig. 4 Egg Turning Control Program Flowchart

Figure 4 shows the egg turning control flowchart, wherein it shows how the egg turning for both chicken and duck eggs is automatically controlled. First, the rollers will start and the egg turning will continue for 5 minutes straight. After 5 minutes, the turning will stop, and the system will wait for 8 hours before doing another cycle. The process will continue until the eggs are mature enough and ready to be harvested.

- **Fertility and Maturity Detection Program**

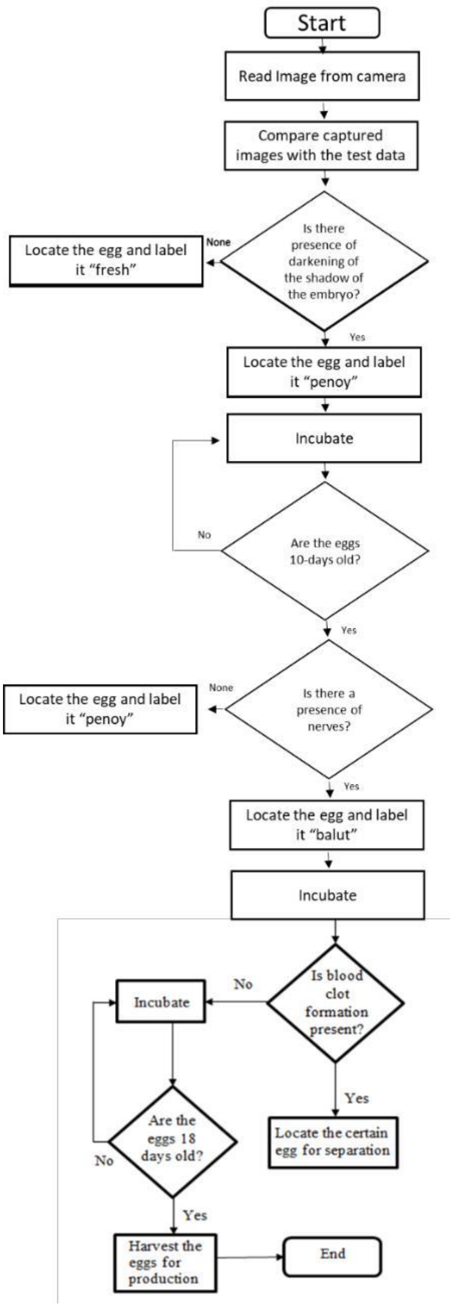

Fig. 5 Fertility and Maturity Detection Program Flowchart

Figure 5 shows a flowchart regarding how the program in the fertility and maturity detection will be executed using the camera-assisted candling apparatus. In the beginning, the images taken by the camera will be compared in the data set gathered. Fertility detection will start by detecting whether the egg has dark spot which is an indication of fertility. Infertile eggs will be located for harvesting while the fertile eggs will be incubated for 10 days more days. The indication for the next detection is the development of the embryo. A presence of nerves is an evidence that the embryo is growing. Eggs with healthy embryos will be incubated and eggs without the presence of nerves will be harvested. Healthy eggs will be incubated until it reaches the 18th day by which all eggs are good enough for *balut* production.

D. Design Implementation

Fig. 6 Incubator Prototype

Figure 6 shows the front view of the incubator. The incubator is 6ft high, 4ft long and 3ft wide. The skeleton of the incubator was made of metal and covered with Hardiflex. It has four layers and each layer is 18 inches high.

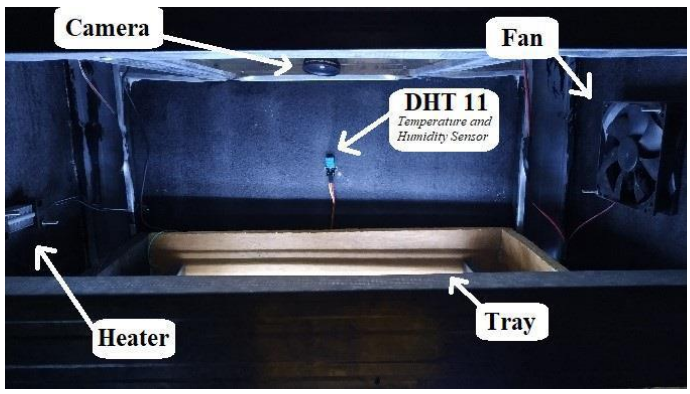

Fig. 7 Incubator Interior Per Layer

Figure 7 shows the setup in every layer of the incubator. The fan was placed in the right side and the heater was placed in the left. The temperature and humidity sensors were placed in the four corners. The tray where the eggs will be placed is made of wood and it has a fluorescent lamp installed inside it.

E. Incubator Testing and Data Gathering

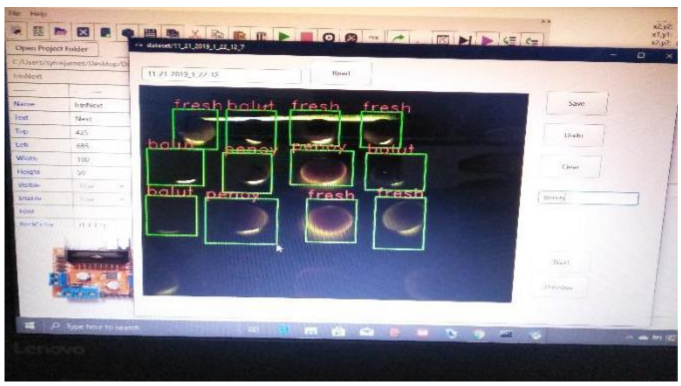

Fig. 8 Data Annotation for Machine Learning

Figure 8 shows the process of labelling the data gathered from using the Automated-candling Machine. In the image, it is visible that the eggs were classified into three classes namely *fresh*, *balut*,and *penoy*. The process of data gathering involves many pictures taken while the eggs were being rotated to ensure no bias when it comes to the other side of the egg.

III. RESULTS AND DISCUSSION

A. Efficiency of the Incubator

a. Temperature Control

The Temperature was regulated by first measuring the temperature with the DHT11 that will then show the readings on the GUI and the program will then decide whether to open the fans or not to maintain the desired temperature which is 35 – 37 degrees Celsius.

b. During the incubation process, the temperature regulation was monitored from day 1 to 18.

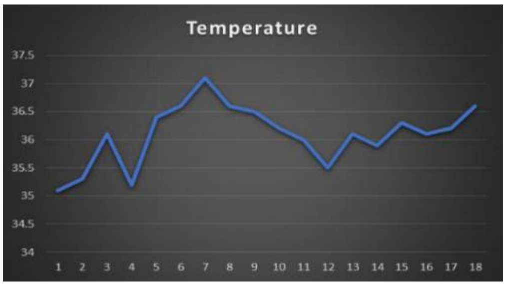

Fig. 9 Temperature Readings from day 1 to 18

Figure 9 shows the regulation of the temperature in one incubation of eggs. Data shows that the incubator was able to maintain the temperature within 35 to 37 degrees Celsius daily which is the optimal level.

B. Traditional Candling versus Automated Candling

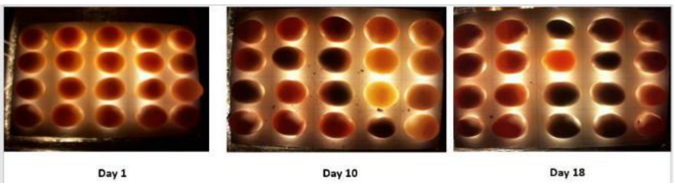

Fig. 10 Growth if the embryo from day 1 to 18

Figure 10 shows the development of the embryo from day 1 to 18. Based on the figure, the indicator that there is a growth is the darkening of the egg. The egg which has the darkest color is classified as *balut*, the darker shade is the *penoy*, and the lightest shade of the egg is the infertile egg or fresh egg.

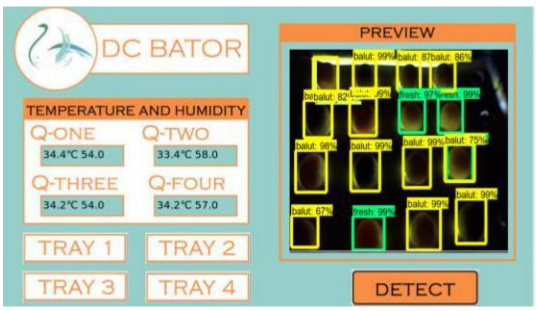

Fig. 11 Automated Candling

Figure 11 shows the User Interface used in automatic candling of eggs. In the GUI, the temperature inside the incubator is displayed. The buttons named with tray numbers will be clicked and the candled eggs will be displayed with their corresponding classification.

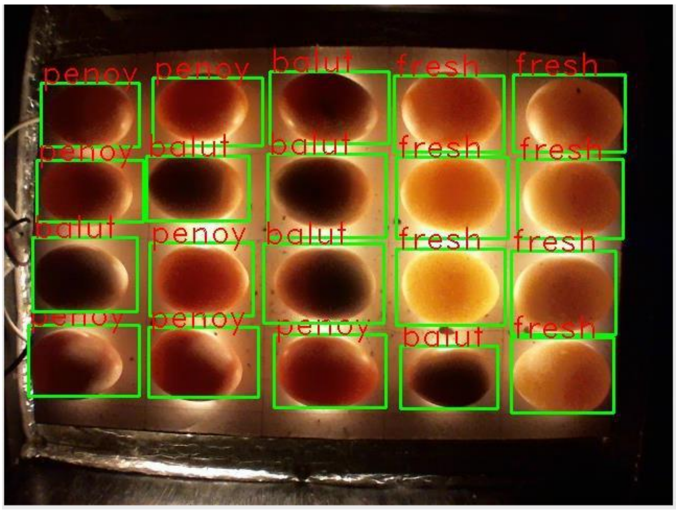

Fig 12. Manual Candling

Figure 12 shows the manual candling process. The incubated eggs were manually classified as *balut, penoy* and fresh based on the darkness of the shadow made by the embryo in the egg.

Tray 1			
Manual Candling		**Auto Candling**	
Egg #	**TIME(s)**	**Egg #**	**Time (s)**
Egg 1	3s	Egg 1	
Egg 2	3s	Egg 2	
Egg 3	3s	Egg 3	
Egg 4	3s	Egg 4	
Egg 5	3s	Egg 5	
Egg 6	3s	Egg 6	
Egg 7	3s	Egg 7	
Egg 8	3s	Egg 8	
Egg 9	3s	Egg 9	
Egg 10	3s	Egg 10	1s
Egg 11	3s	Egg 11	
Egg 12	3s	Egg 12	
Egg 13	3s	Egg 13	
Egg 14	3s	Egg 14	
Egg 15	3s	Egg 15	
Egg 16	3s	Egg 16	
Egg 17	3s	Egg 17	
Egg 18	3s	Egg 18	
Egg 19	3s	Egg 19	
Egg 20	3s	Egg 20	
Total	60s	Total	

Table 1. Candling Time Comparison

Table 1 shows the difference between the time it takes to candle the eggs manually and automatically. It shows that automatic candling of eggs is 60 times faster than manual candling of eggs since, manual candling was done individually while automatic candling is done per tray.

Trial No.	Accuracy
1	80%
2	85%
3	80%
4	75%
5	80%
6	80%
7	80%
8	80%
9	85%
10	80%
Average	80.5%

Table 2. Automated Candling Accuracy

Table 2 shows the accuracy of the automated candling. The incubated eggs were candled manually and automatically. The results gathered in both candling processes were recorded in a table and being compared manually to determine the accuracy of the automated candling process. It was done ten times and it shows that the average accuracy of the automatic candling apparatus is 80.5%

Parameters	Previous work [6]	This work
Number of Dataset Images	750	436
Classification Algorithm	Neural Network Model (NNM)	Regional Convolutional Neural Network (RCNN)
Duck Eggs to be classified	Balut and Rejects	Balut, Penoy, and Fresh
Classification Accuracy	76% with 7% false positives	80.5%

Table 5 Comparison between Previous and Current study

Table V shows the comparison between the previous study [6] and the proposed system. In this study, the datasets used are less than the previous work while the current study has an accuracy 80.5% classifying eggs by three categories, fresh penoy and balut, exceeding the accuracy of the previous work with 76% and having 7% false positives which it only classifies the eggs by two categories, balut and rejects.

IV. CONCLUSION

Based on the tests and data gathered it can be inferred that The Automated Egg Incubator with Raspberry Pi-Based Camera Assisted Candling and Maturity Detection using Convolutional Neural Network for *Balut* and *Penoy* Production is a good alternative or replacement for the traditional incubator wherein it proved that it has the capability to incubate the eggs properly since the temperature is properly regulated and at the same time the user can automatically candle the incubated eggs. Also, this can reduce the efforts in candling the eggs manually, since it was proven that the automatic candling process has a high accuracy and at the same time it is 60 times faster than the manual candling process due to the used algorithm which is RCNN that garnered an accuracy of 80.5% with only having less dataset and classifying the eggs with more categories.

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