Development of Fertile Egg Detection and Incubation System Using Image Processing and Automatic Candling

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***Abstract*— This paper presents the development of an incubation system for autonomous temperature and humidity control using Arduino microcontroller interfaced and coded using LabView programming. The proposed system also includes important functions to hatch eggs which are candling through infertile egg identification using basic image acquisition, and egg turning that employs crank-rocker mechanism and a hatching chamber. It revolves around fusing all the elements of egg incubation and turning it into one device. It functions autonomously without having to consistently check and adjust to obtain optimal parameters. By using its monitoring features, the user can have real-time data of the day-to-day status of the incubator's parameters. The speed of its automatic candling program is 1.129 seconds while the performance of the incubator held an optimal temperature of 36º Celsius with humidity between 40% and 60% with an optimal level of 50%. Lastly, the hatch rate percentage of the incubation using the proposed system is 69.44% while the percentage accuracy result for detecting fertile eggs is 91.43%.**

Keywords—candling, image processing, incubation, fertile egg detection, hatching, turning

I. INTRODUCTION

Artificial incubators have been popular throughout the modern world as well as in the past way back ancient times. Based on historical records, [1], citing [2] and [3], mentioned that in ancient Egypt, eggs were incubated inside buildings which are made up of mud bricks divided by rooms and heated by burning straw and charcoal. They control the temperature by opening vents and manholes for the heat to escape and have openings for the smoke to exit. Humidity is induced by placing moistened jutes inside and eggs were manually turned twice per day. It was not until the 1749 that the first mechanical incubator was invented by Reamur in Paris, France and the first incubator to be commercialized was the work of Hearson in 1881 [1].

Artificial egg incubators' objective is to recreate a brooding hen's environment so that the eggs would hatch into a healthy chick. The parameters or factors that are needed to be controlled by the incubator are temperature, humidity, ventilation and egg turning. If all of these factors are regulated, this will provide the perfect environment for the development of the embryo. As technology advances more and more manual techniques turns into automated processes. Commercial state-of-the-art hatcheries now have sensors that detect these certain parameters and adjust it according to the optimal value so that there will be no discrepancy in the incubation process. Though technological advancements have riddled the field of incubation of eggs, incubation may still run into several issues. The breeder needs to check these common incubation problems: temperature difference inside the incubator, as well as humidity, inadequate ventilation, irregular turning of eggs and egg sanitation [4]. With this, an incubator must possess a reliable program and hardware system and an accurate reading from its sensor so as to function as an effective incubator to handle the eggs for 21 days straight without requiring any human intervention [5]. Also, candling of eggs need to be done by hand because traditional candling is done manually. Besides being a tedious job because the handler must individually check for development of an egg, the temperature changes of handling the egg outside the incubator can also affect the mortality rate of the eggs [6]. There are many digital techniques [7-11] that differentiate good eggs for incubation and bad eggs that are not fit for it, though these researches do not apply specifically for detecting fertile eggs but these studies greatly influence viability for incubation. One method "applied an adaptive threshold based on discontinuities determination of the filtered images for detecting eggshell defects such as dirt and cracks" which used 120,640 by 480 images to train the machine vision system which had an accuracy of 99% [6]. Other studies include finding blood spots and obtaining dirt severity to classify the eggs as infertile as this influences egg fertility, such is the case of M.H. Dehrouyeh et al. They have obtained an accuracy of 90.66, 91.33, 80.33% on finding blood spots of egg from intact, defected and low dirt eggshells respectively and 88% and 86% for dirt detection on high dirt and low dirt in eggshells respectively [8]. "A near-infrared hyperspectral imaging system was created to spot fertility and embryo development. After imaging on each day, developing embryos in randomly selected eggs were stopped by injecting sodium azide (NaN_3)." All the eggs were classified into two: fertile and non-fertile eggs. This study is not like the others as accuracy degrades for day 1 and 2 of incubation. Results stated as day 0 accuracy is at 100%, 78.8% at day 1, 74.1% at day 2, 81.8% at day 3, and 84.1% at day 4. Results showed that

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texture information is more suitable to detect early embryo development than detecting fertility before incubation [9]. All these devices proved to be accurate and efficient in detecting fertility of eggs. However, there is one problem. All of these mentioned are separate devices that can only be functional if the eggs are transferred from the incubator.

The impracticality of removing eggs from the incubator to check growth development and fertility is tedious and is time consuming if it is done on a large number of eggs. As a solution to the problem, an egg candling mechanism inside an incubator was incorporated and designed which in turn will reduce the time invested in candling and will detect undeveloped eggs and classifies it from the rest of developing eggs to avoid the contamination of the incubator due to the phenomena of “exploding eggs” and premature death of chicks due to mishandling of eggs; and an effective system for temperature and humidity control to produce the optimal incubator parameters for the development of chicks. The quality of embryonic eggs is affected by pre-incubation factors that influence the egg hatchability, chick quality, bird survival and chick growth performance [1]. The optimal temperature for the incubation of eggs is 37º to 37.5 º C and relative humidity of 55% [12, 13]. Temperature and humidity sensors were used to determine the condition of the incubator and automatically change for the appropriate condition for the egg [5]. This study is limited only to different chicken egg breeds with white shelled eggs. For the candling function this study includes a camera that will capture an image during the 10th day of incubation to distinguish these eggs that were not developed to efficiently remove these undeveloped eggs.

Poultry hatching businesses will benefit in this study as it will help lessen the time and human contact by automating candling process and remedies the improper way of controlling the temperature and humidity inside the incubator which in turn leads to unfertilized eggs. Through this study, the two major parameters: humidity and temperature will be accurately monitored and controlled and candling of eggs which has been manually done will be electronically achieved through the use of a custom designed tray and a vision system that strategically uses the LabView programming software to identify infertile and fertile eggs.

II. Methodology

A. Block Diagram

Figure 1 shows the block diagram for the autonomous incubator. The inputs in the system of this study are the temperature and humidity sensors, the camera which will capture the image of the egg during candling process and the power source. Automatic control of the incubator is achieved through the sensing of parameters by the DHT11 sensor installed therein. Then these data are processed by the microcontroller in which it decides whether it will switch the devices that will control these parameters: humidity, temperature, and ventilation.

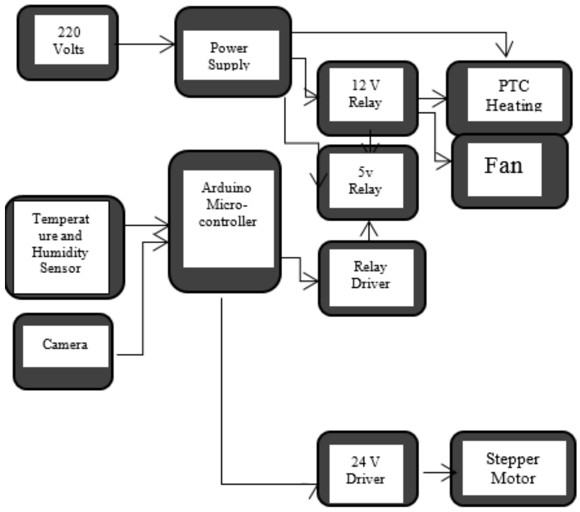

Fig. 1. Block Diagram of the Proposed System

B. Hardware Development

Figure 2 below shows the dimension of the proposed incubator and the placement of chambers where the biggest one is the incubation chamber the smaller ones on the left side is the laptop room and hatched chick room while the chamber farthest to the left is the circuit room. All image-processing hardware is installed at the top of the incubation chamber

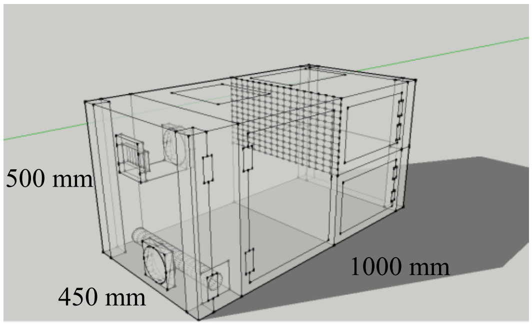

Fig. 2. Physical Design of the Proposed Incubation System

C. Temperature and Humidity Correction System

The correction system as shown in Figure 3 for the temperature fluctuations consists of the PTC heating element partnered by fan and the detection system is Arduino Nano with DHT 11 sensor. Once the temperature drops below the threshold, the detection system sends a signal to the correction system turning on the whole system and turns off if temperature exceeds threshold. The temperature sensor is installed at the far side of the tray directly in the line-of-sight of the fan distributing the heat.

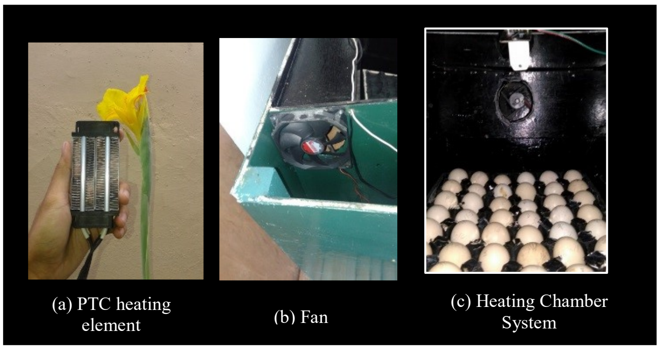

Fig. 3. Physical Design of the Proposed Incubation System

D. Egg-Turning Motor Control System Design

The crank-rocker mechanism as shown in Figure 4 is a type of four bar mechanism where one arm achieves full rotation while the other mechanism only "rocks" in its position. The crank rocker design was a suitable design for achieving an angle exactly 45 degrees tilting for the tray. Also it was suitable for the space requirement since the design does not need much space to cover for installation inside the incubator. As shown in Figure 4 and denoted by Equation 1, variables **a** and **b** will be the rotating arm, **c** is the length of the joint from the rotating point of tray, and **d** is the distance between the two rotating points; one for the motor and one for the tray.

In the design of the egg turning mechanism, the tray should oscillate 45 degrees in an upward and downward motion, so the angles of extremities in which the R_4 bar will make must be considered. R_4 must make a right angle from its initial position up to its maximum extension. The reason for this is because the R_4 bar in the actual design will be length of the tray. The tray will be horizontally aligned with the 45-degree angle that R_4 makes from its initial position up to its maximum extension. As the mechanism oscillates the tray will achieve the 45 degrees oscillation from the x-axis where the tray is aligned.

$$be^{i\theta_3} - ce^{i\theta_4} = -ae^{i\theta_2} + de^{i\theta_1} = Z \tag{1}$$

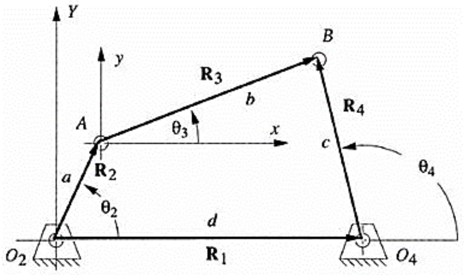

Fig. 4. Crank-rocker Mechanism

The unknown variables for the equation are on the left side and the known variables are on the right which would be represented as Z. Z bar is the conjugate equivalent of the first equation.

$$t = \frac{-(Z\bar{Z} + c^2 - b^2) \pm \sqrt{(Z\bar{Z} + c^2 - b^2)^2 - 4c^2 Z\bar{Z}}}{2c\bar{Z}} \tag{2}$$

In designing a crank rocker mechanism, arm lengths a, b, c, and d should be given and $\boldsymbol{\theta_1}$ and $\boldsymbol{\theta_2}$ should define the arm's initial position, **t** will be the output angle and since there will be 2 solutions it will be related to open and crossed positions of the arms.

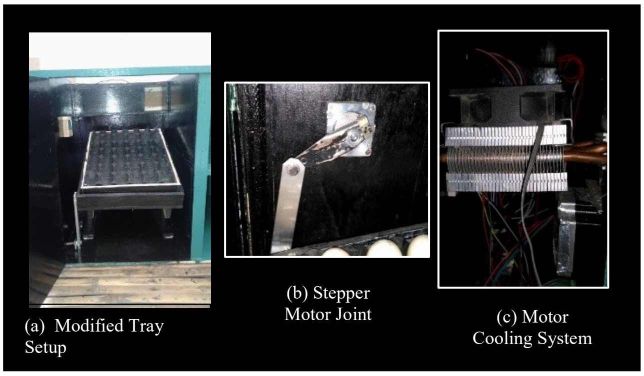

Fig. 5. Egg-Turning System

The modified tray has LED strip lights below where eggs can be illuminated without removing the eggs from the tray has been installed. Egg turning mechanism that employs a crank-rocker inspired design turns the eggs 45 degrees both sides every 8 hours per day. The timing program is uploaded in the Arduino Nano. The stepper motor is installed with a fan cooling system partnered with heat sink to reduce the heat the motor is experiencing. An egg turning system is needed in order for the growing embryo to not bind into the membrane of the eggshell [14].

E. Camera-Assisted Candling System

Figure 6 shows the program flow on how the software operates. First, the program reads the image then starts processing for color detection the program will decide based on the color of the eggs. If the eggs are still translucent after days of incubation, the program will detect it otherwise it will not.

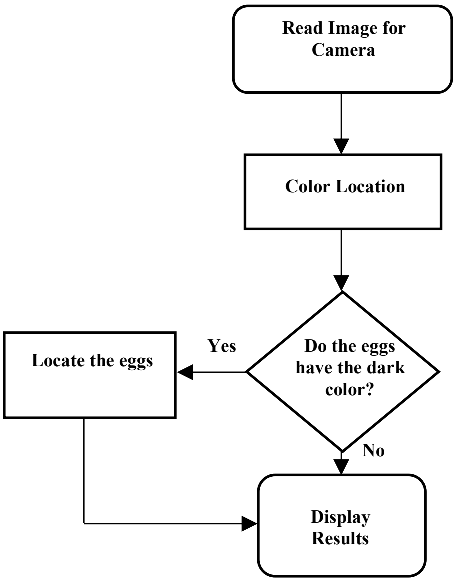

Fig. 6. Image Processing Program Flowchart

The camera is installed directly at the top of the incubator overlooking the tray. The camera should capture all the eggs in the tray so in processing the image all could be color detected and identified whether the egg is a porous egg with no semen or a fertile egg. The programming software used for the processing is LabView with NI Vision Assistant.

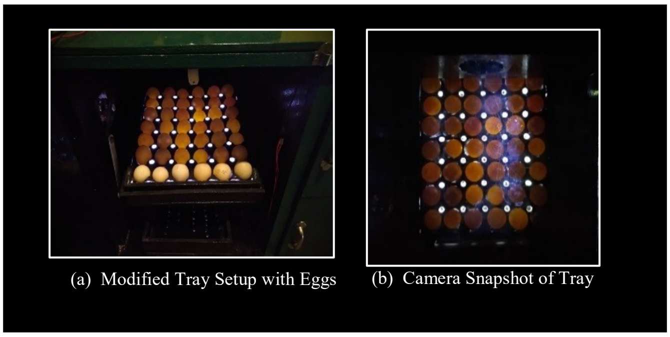

Fig. 7. Modified Tray Setup

Since the distinction between clear (undeveloped) and developing eggs is visible for human eyes, a color space should be used that will be closer to human operator performance. Thus, color location was used. By having an image type of RGB (32-bit) and Day 1 eggs as templates for the image processing, the difference between the eggs can be determined. The steps of the image processing are: 1) input the image of Day 1 eggs as a template for the color location to be used. 2) Adjust the minimum score of the color location setup between 600 to 800 and the color sensitivity to high sensitivity. The researchers used a minimum of seven color location setups for the image processing. The image of Day 1 eggs is critical for determining the undeveloped eggs at Day 10 since the Day 1 eggs are **porous** against Day 10 eggs that have a dark color. By inputting the Day 10 image through the NI Vision assistant program, the undeveloped eggs will be determined.

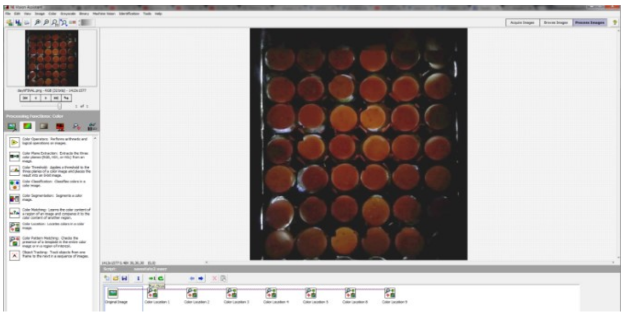

Fig. 8. Candling Program

F. Incubator Testing and Data Gathering

The incubator's system functionality was tested and at the same time data were gathered for validation if the incubator does maintain the right level of humidity and executes the program accurately.

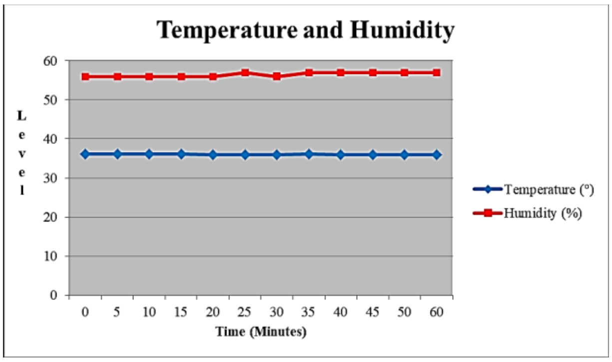

Fig. 9. Temperature and Humidity Level

The incubator's system functionality was tested and at the same time data were gathered for validation if the incubator does maintain the right level of humidity and executes the program accurately. Temperature and humidity is gathered every 5 minutes for an hour to test if the incubator can maintain the optimal temperature and humidity.

Figures 10 & 11 show the performance of incubator for 3 days of continuous usage. Data shows that the temperature was held on to optimal level (36 degrees) and humidity on its acceptable level which is between 40% and 60% with 50% as the optimal level.

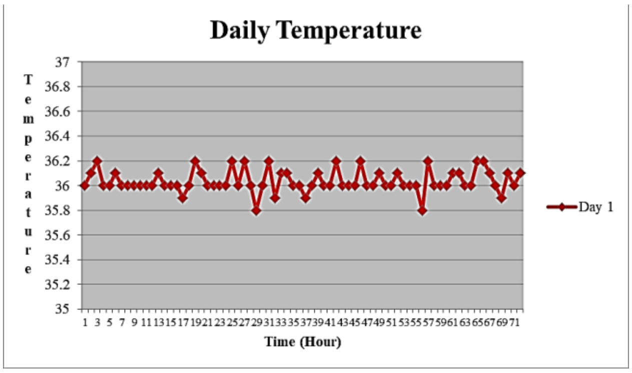

Fig. 10. Temperature Endurance Test Readings of the Incubator for 3 Days

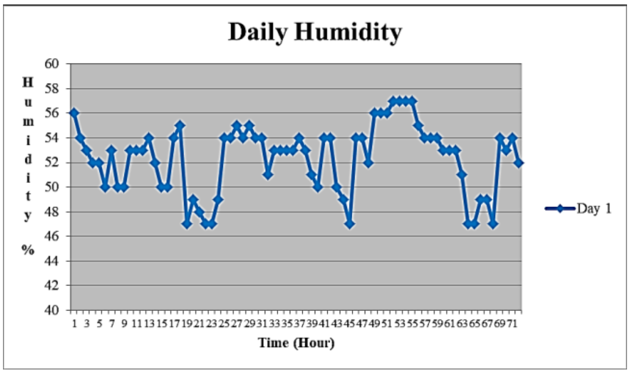

Fig. 11. Temperature Endurance Test Readings of the Incubator for 3 Days

III. Results and Discussion

Figure 12 shows the darkening of eggs which indicates growth of the embryo cultured in the egg while Figure 13 shows the difference in imagery of manually candled eggs and eggs candled using the incubator's built-in candling design. In order to compensate for the lighting discrepancy of the incubator's candling, the researchers used image manipulation to heighten the efficiency of image processing done on the eggs. The threshold in the color changing process which was set for the system is the difference of the dark areas of the eggs for day 1 and day 10. The images captured during these days were feed as training data using LabView image processing toolbox. Once a sample image was tested in the LabView developed program, fertile and infertile eggs will be immediately determined.

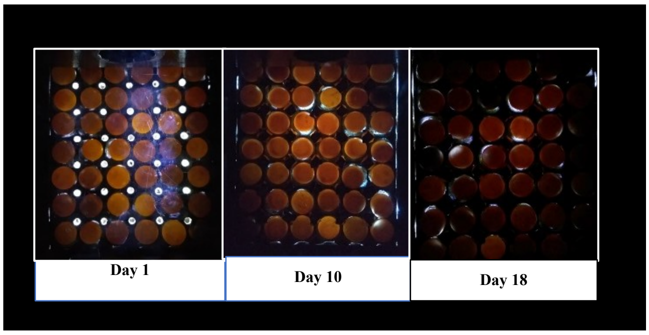

Fig. 12. Incubation Progress

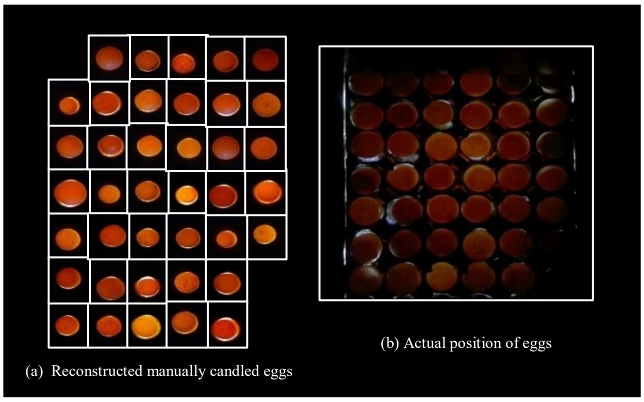

Fig. 13. Reconstructed manual candling versus actual tray candling

A. *Traditional and Automated Candling Time Comparison*

After 3 trials of manual candling, the average time it took for one breeder to candle all 42 eggs was determined to be 396.667 seconds while the time it took for the candling program to process the candling is only 1.129 seconds. By computing for the percent difference, the resulting percentage will be in favor of automatic candling. The automatic candling proved to be 35,034 % faster or 350.34 times faster than traditional candling. The large difference in time is due to the program's nature that it detects all the eggs through one picture only while in manual candling the eggs are individually assessed.

B. *Traditional and Automated Candling Accuracy Comparison*

During the sensory comparison evaluation of the eggs in the proposed system by the breeder in the farm, the specialist detected there are 7 eggs that are not suitable for incubation anymore. Four of the seven eggs (Egg #15, 16, 20 and 39) are porous eggs or infertile. These are infertile eggs which do not have semen in the first place while the remaining eggs are eggs that encountered various incubation problems like cracked shell, etc. The camera-assisted candler detected 4 of these infertile eggs but not the other undeveloped eggs. The value for sensory evaluation is 7 eggs detected and for automatic candling the value is 4 eggs detected. As traditional candling is very accurate as it checks for every signs of death in the egg traditional candling garnered 100% accuracy because 7 out of 7 eggs are porous or infertile. Therefore candling accuracy for fertile eggs using traditional method is 100% and for the automated method, since 4 out of 7 eggs have been detected infertile, the subsequent percentage accuracy result for detecting fertile eggs is 91.43%. In which the result have been computed by subtracting the percentage error of 3 out of 35 which is 8.57 % from 100%.

Figure 14 shows the color detection results made by the program in determining the fertility of eggs after the 10th day of incubation. Figure 15a shows the 7 unfertilized eggs (boxed in red0 which are detected using sensory evaluation. 4 eggs are detected as unfertilized using the developed LabView program.

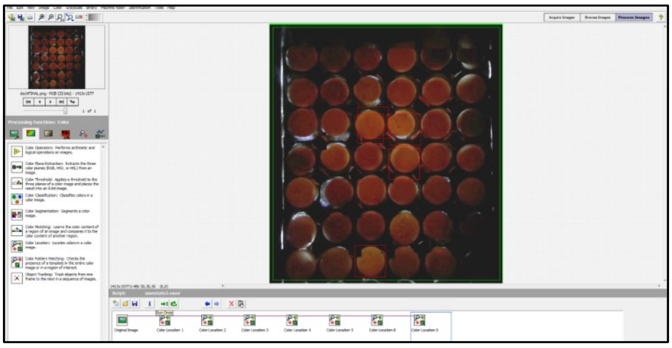

Fig. 14. Color Detection Program of Candling Software

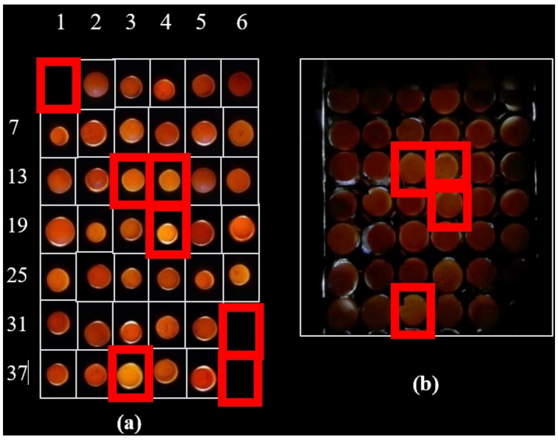

Fig. 15. Comparison of Detected Eggs by (a) Traditional Sensory Method and (b) Proposed System. The Labview program automatically indicates the 4 unfertilized eggs in red squares.

C. *Hatch Rate*

Figure 15 shows the newly hatched chicks from the incubation. They are placed in a warm cage immediately by the farm personnel/ caretaker to ensure their survival.

25 out of 42 eggs were hatched using the prototype incubator which means 18 eggs did not hatch. In those 18 eggs that did not hatch, 7 are detected infertile by traditional candling and the remaining 11 eggs are fertile but had pre-incubation problems. Those 11 eggs have not fully developed during the process of incubation.

The hatch rate percentage of the incubation is 69.44% as 25 out of 36 determined fertile eggs were successfully hatched. Although all the variables in incubation have been considered, variables which are outside the scope of the study that is related to breeding have also a great influence in the disparity between the hatched and unhatched eggs. While the study achieved success in efficient incubation and enhanced monitoring of egg development, hatch rate is still influenced by the health history of the flock, the rooster's breeding ability and genetics.

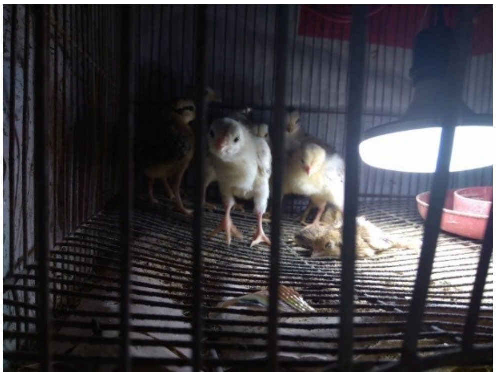

Fig. 16. Newly-Hatched Chicks

IV. Conclusion

Based on the testing conducted and data gathered, it can be inferred that the proposed system is a viable choice or even a replacement from traditional incubators for incubation as it accurately and autonomously reads and maintains temperature and humidity, controls egg turning and reduces time and effort in candling the eggs as it hastens candling process using image processing and effortlessly monitor egg development due to ingenious design of built-in candling apparatus inside the incubator.

Future work includes modification of the incubation heating and ventilation system to improve the hatch rate of the eggs.

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References

[1] I. C. Boleli, V. S. Morita, J. B. Matos Jr, M. Thimotheo, and V. R. Almeida, "Poultry Egg Incubation: Integrating and Optimizing Production Efficiency," *Revista Brasileira de Ciência Avícola*, vol. 18, no. SPE2, pp. 1-16, 2016.

[2] M. Paniago, "Artificial incubation of poultry eggs - 3,000 years of history," *Hatchery Expertise Online,* pp. 1-3, 2005. [Online]. Available: http://www.thepoultrysite.com/focus/contents/ceva/OnlineBulletins/ob_2005/Article-No2-Sept05.pdf. [Accessed: Mar. 1, 2018].

[3] W. Van der Sluis. "Egyptians hatch eggs the tradtional way," *World Poultry,* vol. 27, no. 3, p. 18, 2011.

[4] A. M. King'Ori, "Review of the factors that influence egg fertility and hatchability in poultry." *International Journal of Poultry Science,* vol. 10, no. 6, pp. 483-492, 2011.

[5] P. E. Okpagu and A. W. Nwosu, "Development and temperature control of smart egg incubator system for various types of egg," *European Journal of Engineering and Technology*, vol. 4, no. 2, 2016.

[6] M. Hashemzadeh and N. Farajzadeh, "A Machine Vision System for Detecting Fertile Eggs in the Incubation Industry," *International Journal of Computational Intelligence Systems*, vol. 9, no. 5, pp. 850-862, 2016.

[7] H. R. Pourreza, R. S. Pourreza, S. Fazeli, and B. Taghizadeh, "Automatic detection of eggshell defects based on machine vision." *Journal of Animal and Veterinary Advances*, vol. 7, no. 10, pp. 1200-1203, 2008.

[8] M. H. Dehrouyeh, M. Omid, H. Ahmadi, S. S. Mohtasebi, and M. Jamzad, "Grading and quality inspection of defected eggs using machine vision," *International Journal of Advanced Science and Technology*, vol. 17, no. 4, pp. 23-30, 2010.

[9] L. Liu and M. O. Ngadi, "Detecting fertility and early embryo development of chicken eggs using near-infrared hyperspectral imaging," *Food and Bioprocess Technology*, vol. 6, no. 9, pp. 2503-2513, 2013.

[10] K. Das and M. D. Evans, "Detecting fertility of hatching eggs using machine vision II: neural network classifiers." *Transactions of the ASAE*, vol. 35, no. 6. pp. 2035-2041, 1992.

[11] B. Shan, "Fertility Detection of Middle-stage Hatching Egg in Vaccine Production Using Machine Vision," *2010 Second International Workshop on Education Technology and Computer Science*, Wuhan, 2010, pp. 95-98.

[12] G. S. Archer, and A. L. Cartwright, "Incubating and Hatching Eggs," Texas A&M Agrlife Extension Service, pp. 1-13, 2012.

[13] T. A. Adegbulugbe, A. O. Atere, and O. G. Fasanmi, "Development of an Automatic Electric Egg Incubator," *International Journal of Scientific & Engineering Research*, vol. 4, no. 9, pp. 914-918, 2013.

[14] O. Elibol and J. Brake, "Effect of egg turning angle and frequency during incubation on hatchability and incidence of unhatched broiler embryos with head in the small end of the egg," *Poultry science*, vol. 85, no. 8, pp. 1433-1437, 2006.