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A cost-effective approach for chicken egg weight estimation through computer vision

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Abstract

Egg weighing and classification are among the most significant phases done in egg processing by industries which are tedious if done manually by poultry owners, and egg inspectors and graders. This study presented an alternative way of estimating chicken egg weight through computer vision minimizing human interaction during the process. In this study, 15 eggs of white leghorn chicken layers of different sizes were tested. The eggs' image was captured using an inexpensive yet reliable webcam which was then loaded onto the Matlab workspace for image processing and further image analysis. The center of gravity of the image was determined, and the extraction of minor axis length and major axis length followed. The obtained values were used to compute the egg's weight mathematically. Through the different image processing methods, image dimensions were extracted and used to calculate the desired output. The results of this study showed 96.31% accuracy in estimating the egg's weight and classification validated by manual egg weighing and classification procedure.

Keywords: Egg weight, webcam, image processing, image analysis

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Introduction

Poultry egg production has indeed provided excellent opportunities to poultry farmers in the Philippines. According to the report of the Philippine Bureau of Agricultural Statistics, for five consecutive years starting 2009, egg production had the following increase percentage: 1.53%, 4.01%, 4.52%, 4.61%, and 5.11% (CountrySTAT-Philippines, 2014). However, poultry owners are burdened by hiring additional workers for their poultry farms to do the different routinary tasks viz. egg harvesting and collection, cleaning and washing of eggs, segregation of cracked and non-cracked eggs, egg grading and classification, and sorting and packaging. Moreover, these are apparently tedious works, especially when done manually.

Egg weighing is one of the essential phases of egg processing. Egg inspectors and graders must carefully examine and check the eggs before it will be packed for market distribution. The problem is that it takes a lot of human effort to do this work which necessitates the search for a more convenient yet less expensive alternative. This is the reason why researchers are developing an alternative way of doing this through computer vision.

As of now, there are already existing egg sorter and packaging machines that are available globally, and there are even existing researches on egg weight estimation using computer vision involving more components (Dangphonthong and Pinate, 2016). Their ultimate goal is to help those poultry farm owners, egg graders, and inspectors to do their jobs right. However, although there are already studies developed in this domain such as the study of Abdanan Mehdizadeh et al., (2014), Soltani et al. (2015), and Waranusast et al. (2016), one of the main concerns is the cost of developing the set-up.

An existing study of egg weight estimation was presented using a machine vision system combined with artificial neural network technique (Asadi and Raoufat, 2010). In this research study, an alternative method for estimating chicken egg weight through computer vision was developed. This computerized method of egg weight estimation used a simple and less expensive but reliable webcam aided with software. This system featured the following image processing method: image acquisition, pre-processing, detection, and analysis of an egg image to acquire the desired result. Consequently, this system will determine the egg's weight and classification.

This study aims to show that even an inexpensive webcam with the aid of software can be used to estimate an egg's weight from a distance without human interaction through computer vision. Furthermore, this study aims to develop a less expensive automated chicken egg weight estimation method which is indeed economically beneficial in the long run.

Materials and Methods

Physical Setup

The system's hardware specifications were suitably chosen based on the compatibility of the programming language used for image processing and the computer vision device (webcam). It only used a low-cost webcam for image acquisition.

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Figure 1 below shows the physical setup of the egg weight estimation system. The prototype housing was made out of a ply board to support the webcam on its top which was positioned perpendicular to the inspected egg. The egg was placed in a hole of a candling booth so that the light would penetrate to the egg and making it possible to observe the egg's shape and edges.

The indicated dimensions of the system's prototype shown in Figure 2 were very well-observed because of its effect on the image processing result when not done correctly. The working distance between the front of the webcam lens and the object was set to 14 cm. When the object's height parameter was set to 15 cm or below, the nonlinearity has less impact on the system accuracy. The error variation by this setting is acceptable (Chmelař and Dobrovolný, 2012). Though a working distance of 15 cm to 1 cm could have a fair result, the researcher opted to choose 14 cm so that the image of a bigger size egg could still fit on the frame. Bigger eggs appear larger than the frame if the working distance is 13 cm. According to Euclid's law, the farther away an object is, the smaller it appears; consequently, the closer the object from the viewer, the bigger it seems.

The interior portion of the box was themed black to darken the area for candling purposes. Egg's defect detection using candling method could be easily observed in a dark room (Broyde, 2000). This candling booth contained a lighting system (5W softone standard bulb with its receptacle). Once it was lighted on, the light penetrates into the egg's shell which then enabled the camera to detect its shape.

This research used eggs of a white leghorn chicken layers since it is the common chicken layer breed used in medium- to large-scale poultry egg production in the Philippines. The egg's shape of this breed of chicken is typically axial symmetric concerning its major axis. It was assumed that the eggs to be inspected using this system are fresh so that the density which is 1.031 g cm^{-3} will be applicable (Paganelli et al., 1974). It was also assumed that before the eggs are placed onto the system; they were already washed and cleaned, so dirt like blood, feather, feces or mud and even those cracked eggs if any were already removed. For demonstration, this system only does the pick and drop method in placing the eggs horizontally beneath the camera.

The block diagram of the egg weight estimation system as shown in Figure 3 consisted of 5 steps: (1) Image acquisition, (2) Image pre-processing step, (3) Image enhancement technique, (4) Image segmentation and (5) Image analysis.

System Design

To achieve the desired output by estimating the egg's weight, this system had gone through the following processes:

a. Image acquisition

Image acquisition is the process of capturing the egg's image to be processed through a low-cost webcam. To get the best image the webcam could capture, it was set to its highest capable resolution which is 640 x 480, and the returned color space was set to grayscale. It carries the intensity information where black have the low or weakest intensity, and white have the high or strongest intensity. The boundary between these two regions forms the edge. Edge detection operator was then applied to detect the object boundaries and edges (Al-amri et al., 2010).

b. Image pre-processing

The grayscale image was converted to a binary image using a threshold value determined by the program. That is when the image intensity is less than the threshold value; it would be replaced with black, otherwise, a white pixel if the image intensity is greater than that value. This grayscale transformation helps to make the image clearer for easy image boundary detection.

c. Image enhancement technique

This step increases the signal-to-noise ratio and accentuates image features by modifying the colors or intensities of an image. It involved image noise removal with linear, median, or adaptive filtering.

d. Image augmentation algorithm

In this step, the program determined the region boundaries of the image. This system used edge-based methods. Once the boundary was already identified, the entire area of the image was filled with white pixels to make the image look solid.

e. Image analysis

This is the phase of extracting the image's meaningful information such as determining the region of interest, finding the center of gravity and measuring object properties. Since egg image formed an elliptical shape, there were 2 axis lengths present in the image, the minor axis length and the major axis length concerning its center of gravity or centroid. Figure 4 shows the egg image's minor axis (breadth) and the major axis (length). This image property was measured (in pixel).

The calculated distance in the pixel value of the minor and major axis length, converting pixel to the real-world unit (in cm) followed. It was accomplished by multiplying the distance value (in pixel) of the minor and major axis length with the spatial calibration factor, 0.0111 cm per pixel. A constant value of 0.0111 cm per pixel was being used during the calculation. This spatial calibration factor is only for this setting. Spatial calibration factor allows one to translate a measurement from pixel units into real-world units (National Instruments Corporation). It is dependent on some parameters that were applied to this setup like the resolution of the webcam, the image acquisition software, and the distance and environment of the working area.

The formula in Eq. 1 was used to calculate the egg's volume, where, *L* is the egg's length (converted in cm) obtained through measuring the image major axis length and *B* is the egg's breadth (converted in cm) obtained through measuring the image minor axis length (Altuntas and Sekeroglu, 2010).

$$V_{egg} = \left(\frac{\pi}{6}\right) \times LB^2 \qquad \text{(Eq. 1)}$$

With the obtained value of the egg's volume (in cubic cm), computation of the egg's weight using the mass formula follows. The formula to determine egg's mass was shown in Eq. 2, where V_{egg} value was replaced with the calculated egg volume value (in cubic cm) taken from the previous step and 1.031 g cm^{-3} was the density of the fresh chicken egg (Paganelli et al., 1974).

$$m_{egg} = V_{egg} * 1.031 \qquad \text{(Eq. 2)}$$

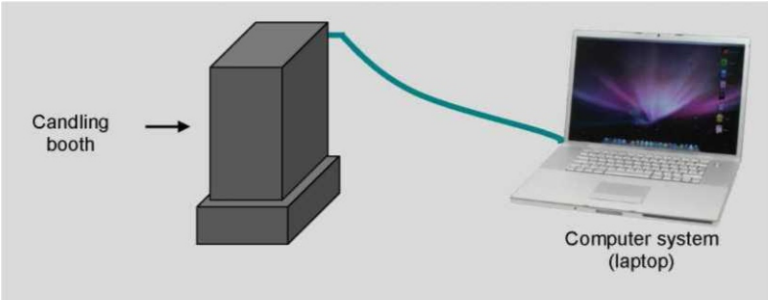


Figure 1. Physical Setup of the Egg Weight Estimation System

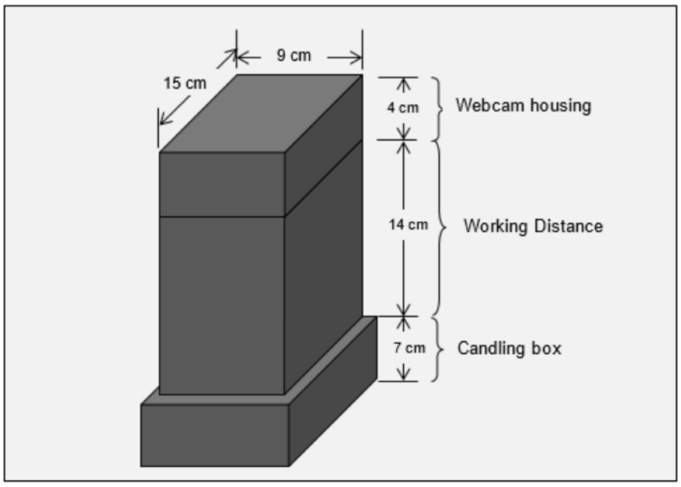


Figure 2. Parts and Dimensions of the System Prototype

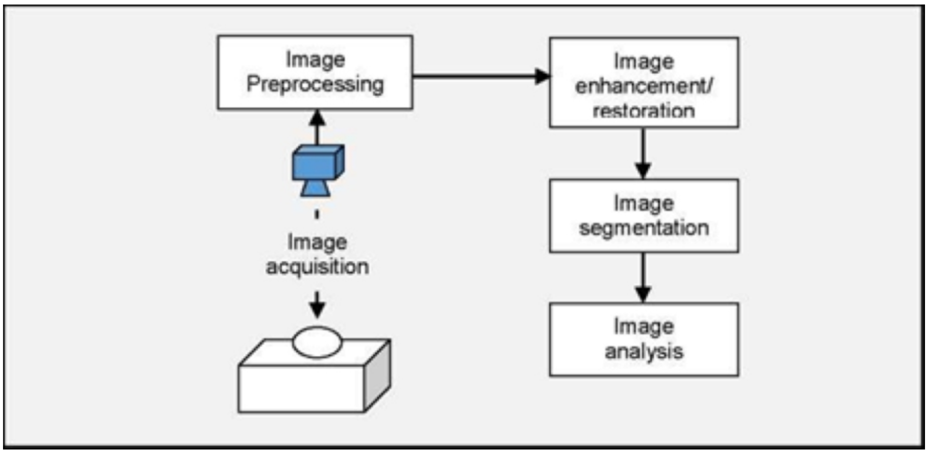


Figure 3. Block Diagram of the Egg Weight Estimation System

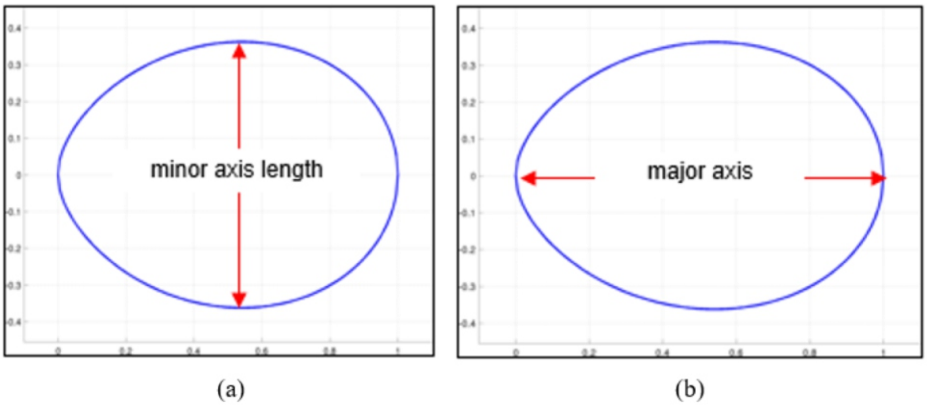


Figure 4. (a) Minor Axis (Breadth) and (b) Major Axis (Length) of an Egg

With the computed egg's weight (in gram) from the previous step, egg size classification followed by evaluating the egg's mass value based on the categories given by the Philippine National Standard for Table eggs (PNS/BAFPS, 2005).

User Interface Design

The programming language used in this system is Matlab R2012b. It had the following image processing related toolbox: computer vision system, image acquisition, image processing and GUI. Using the guide Matlab command, the algorithm for chicken egg weight's estimation is shown in Figure 5.

Evaluation of the System

To assess the effectiveness of chicken egg weight estimation system, it was tested to 15 fresh chicken egg samples that come in different sizes. The 15 egg samples were first weighed manually using an analytical balance. The measured values were then compared to the result of the egg weight estimation system.

After the manual weighing of the 15 fresh egg samples, they were loaded individually to the developed system for inspection. Each egg was being inspected 12 times or in 12 trials. These 12 trials were divided into four positions. These four (4) positions thought to be the possible positions of the eggs when loaded in a conveyor or egg holder during the inspection. Each position had 3 trials to test the system accuracy. In the first position (Position 1), the egg was positioned horizontally, parallel to the camera's orientation. In the second position (Position 2), the egg's position was changed, rotating it 10-15° from its original position (Position 1). While in the third position (Position 3), the egg was rotated up to 180° from its original position (Position 1). And finally, for the fourth position (Position 4), the egg was held vertically 10-15° inclination point from its original position (Position 3). Three trials (Trial 1, Trial 2 and Trial 3) were conducted for each position. Figure 6 shows the captured image of different egg positions.

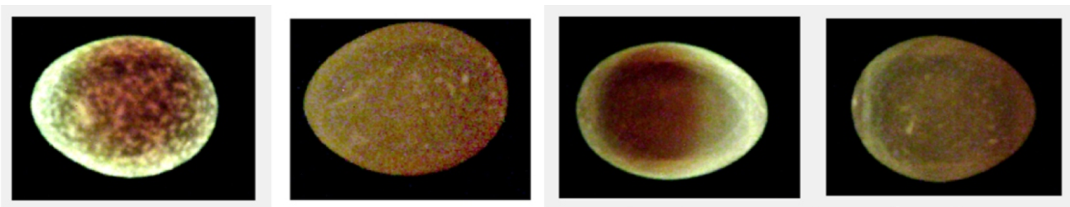
Table 1. Table of egg classification with their corresponding weight

Weight class	Weight range (in grams/egg)
Jumbo	70 and above
Extra Large	65 – 70
Large	60 – 65
Medium	55 – 60
Small	50 – 55
Pullets	45 – 50
Peewee	40 – 45
Too light	< 40

PNS/BAFPS 35:2005

```
Initialize image acquisition device
Set Image Acquisition device
Access image acquisition
Get image snapshot
Save snapshot

Load image on the workspace
Convert grayscale image to binary image

Filter binary image
Remove objects inside the image which pixel less than 20
Fill holes enclosed the boundary

Locate the image's center of gravity
Get the minor axis length of the object, in pixel
Convert pixel value to centimeter

Locate the major axis length of the object
Get the major axis length in pixel
Convert pixel value to centimeter

Compute the egg volume
Compute the egg mass/weight
Classify the egg's size through the calculated egg mass/weight
If mass/weight is greater than or equal to 70, print "Jumbo",
    Else if the mass/weight is greater than or equal to 65, print "Extra Large"
    Else if the mass/weight is greater than or equal to 60, print "Large"
    Else if the mass/weight is greater than or equal to 55, print "Medium"
    Else if the mass/weight is greater than or equal to 50, print "Small"
    Else if the mass/weight is greater than or equal to 45, print "Pullet"
    Else, print "Peewee"
```

Figure 5. Algorithm for Chicken Egg Weight's Estimation



Position 1 Position 2 Position 3 Position 4

Figure 6. Captured Image of Different Egg Positions

The reason for having these different positions is to evaluate the efficiency and accuracy of the system in estimating chicken egg weight and size classification even when the positions of the eggs are at different perspectives.

Using percent error formula on Eq. 3, the researcher was able to check the developed system's accuracy. It compares the system's obtained value to the measured value. The manual measurement (weight) in Eq. 3 is the measured value of the egg's weight using a weighing scale, while computerized measurement (weight) is the value of the egg's weight generated from the developed system.

$$\% \text{ Error} = \frac{\text{manual measurement (weight) - computerized measurement (weight)}}{\text{manual measurement (weight)}} \text{ x } 100\% \quad \text{(Eq. 3)}$$

Results and Discussion

Figure 7 shows a sample output of the egg weight estimation system. This user interface would be prompted on the screen for visual inspection to see the egg's properties during inspection and classification. It displayed the images used in the image processing and analysis, like the captured image, binary image, and the measured image. It also displayed the calculated egg weight and egg classification. For demonstration purposes, the egg inspector clicked the Inspect Egg button on the interface after the egg was positioned on the egg holder. In not less than 5 seconds, the result was then displayed on the screen.

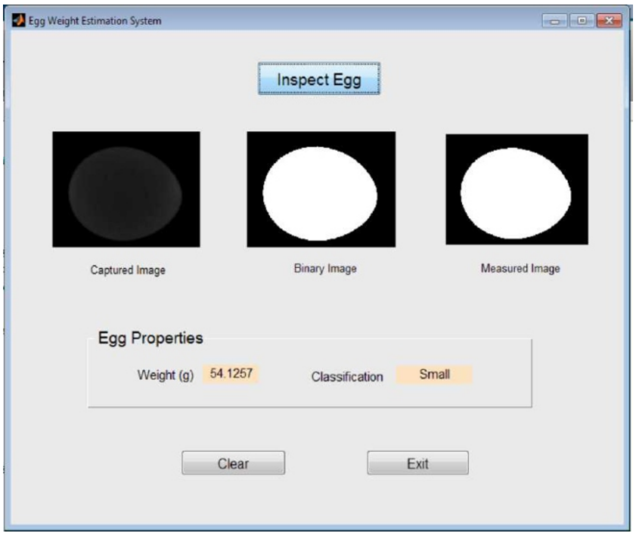


Figure 7. Sample Egg Weight Estimation System Result Output

Comparison between Manual and Computerized Method of Measurement Result

With the obtained egg grading and inspection data from both manual and computerized method, percent error was used to determine the accuracy of the system. The eggs were positioned in four different ways as follows:

a. Egg positioned parallel to the webcam

In this position (Position 1), the egg was laid on the egg holder parallel to the camera's orientation. Table 2 shows that the percent error of the egg samples ranged from 0.45% - 5.97%, with an average percent error of 3.69%. A percentage error very close to zero means very close to the targeted value. Therefore, this position of the egg samples where the eggs were laid parallel to the camera was a good position to get the egg weight using this system.

Table 2. Egg Weight Estimation Value and its Percent Error (Position 1)

Egg Sample	Weight Estimation (g)		
	Computerized Method	Manual Method	% Error
1	72.87±0.416	74.20	1.80
2	80.36±0.072	80.00	0.45
3	62.39±0.243	64.40	3.12
4	49.55±0.275	52.20	5.07
5	60.35±0.258	62.40	3.29
6	60.81±0.449	64.40	5.58
7	57.17±0.133	60.80	5.97
8	63.35±0.583	65.00	2.54
9	54.09±0.473	56.40	4.10
10	53.85±2.918	56.00	3.83
11	50.38±0.321	53.40	5.65
12	51.26±0.159	53.70	4.54
13	53.26±0.257	55.50	4.04
14	51.48±0.344	53.00	2.87
15	50.67±0.104	52.00	2.56

b. Egg positioned held inclined from its 1st position

In this second position (Position 2), the egg was held inclined or rotated 10-15° from its original position (Position 1). As shown in Table 3, the percent error of the egg samples ranged from 0.03% - 5.22%, with an average percent error of 3.05%. It had a percentage error closer to zero which means that this position could still estimate the egg's weight.

Table 3. Egg Weight Estimation Value and its Percent Error (Position 2)

Egg Sample	Weight Estimation (g)		
	Computerized Method	Manual Method	% Error
1	72.45±0.459	74.20	2.36
2	81.00±0.305	80.00	1.25
3	62.28±0.303	64.40	3.29
4	49.64±0.202	52.20	4.90
5	60.26±0.214	62.40	3.42
6	61.47±0.264	64.40	4.56
7	57.63±0.34	60.80	5.22
8	63.29±0.723	65.00	2.64
9	54.46±0.055	56.40	3.44
10	55.98±0.051	56.00	0.03
11	52.17±0.276	53.40	2.30
12	51.60±0.204	53.70	3.91
13	53.52±0.241	55.50	3.57
14	51.56±0.354	53.00	2.73
15	50.85±0.271	52.00	2.21

c. Egg positioned parallel to the webcam (180° from Position 1)

The egg samples in this position (Position 3) were rotated up to 180° from its first position (Position 1). As shown in Table 4, the percent error of the egg samples ranged from 0.77% - 6.33%, with an average percent error of 3.49%. It also had a percentage error closer to zero which means that this position could still estimate the egg's weight.

Table 4. Egg Weight Estimation Value and its Percent Error (Position 3)

Egg Sample	Weight Estimation (g)		
	Computerized Method	Manual Method	% Error
1	72.84±0.174	74.20	1.83
2	80.71±0.337	80.00	0.88
3	62.30±0.023	64.40	3.26
4	49.50±0.163	52.20	5.18
5	59.93±0.381	62.40	3.96
6	61.64±0.304	64.40	4.28
7	56.95±0.111	60.80	6.33
8	63.60±0.388	65.00	2.15
9	53.86±0.341	56.40	4.50
10	55.57±0.191	56.00	0.77
11	50.46±0.129	53.40	5.50
12	51.47±0.066	53.70	4.15
13	53.06±0.243	55.50	4.40
14	51.91±0.066	53.00	2.05
15	50.39±0.191	52.00	3.10

d. Egg positioned held inclined from its previous position

For this Position 4, the egg was held at 10-15° inclination point from its original position (Position 3). As shown in Table 5 that the percent error of the egg samples ranged from 0.01% - 6.14%, with an average percent error of 3.18%. It had a percentage error still closer to zero which means that this position could still estimate the egg's weight.

Table 5. Egg Weight Estimation Value and its Percent Error (Position 4)

Egg Sample	Weight Estimation (g)		
	Computerized Method	Manual Method	% Error
1	73.32±0.167	74.20	1.19
2	79.99±0.487	80.00	0.01
3	62.30±0.239	64.40	3.26
4	49.75±0.225	52.20	4.69
5	59.50±0.430	62.40	4.65
6	62.03±0.184	64.40	3.69
7	57.07±0.081	60.80	6.14
8	63.54±0.302	65.00	2.24
9	54.24±0.189	56.40	3.84
10	55.85±0.179	56.00	0.26
11	51.47±1.279	53.40	3.61
12	51.75±0.098	53.70	3.63
13	52.86±0.058	55.50	4.76
14	51.90±0.066	53.00	2.08
15	50.12±0.006	52.00	3.62

The estimated egg weight could still be determined mathematically using the obtained measurement value of the egg's minor and major axis length from the image. The results on the previous tables (Tables 2-5) show that the average percentage error ranged only from 3.05% to 3.69%. Comparing the manual measurement and the computerized egg weight estimation system pointed to 3.69% error or 96.31% accuracy. Therefore, this system is capable of estimating the egg's weight through getting the exact egg's dimensions from the captured image by an inexpensive webcam with the aid of a program.

Egg Weight Estimation System over Manual Processing Cost Effectiveness

Small to medium-scale or even large-scale poultry farms determine an egg's weight using either an egg weighing scale or a balance weighing scale. With this presented system, there is no need to acquire an expensive high-resolution camera and a dedicated egg weighing scale at the same time. This system uses an inexpensive webcam in estimating egg's weight. This helped minimized expenses regarding acquiring additional devices and materials.

The more laborers an industry has, the bigger the money to spend for the laborers' wages and additional benefits. With this system embedded in an egg-sorting machine or conveyor, poultry farm owners do not need to hire redundant laborers just to inspect and weigh the eggs individually. For example, instead of hiring two laborers (assigned for inspection and weighing), farm owners may hire only one laborer to do both task's just to supervise and oversee the system. It is already the task of the system to determine the egg's weight for further classification.

As regards to productivity, it is expected that this device could be more productive than manual laborers who operate only during working hours. This system could operate 24/7 if it is integrated with a conveyor within a grading machine.

Conclusion

This automated chicken egg estimation system was tested using 15 fresh chicken egg samples in different sizes. The result showed that the manual measurement and the computerized egg weight estimation system had up to 3.69% error or 96.31% accuracy.

Results in Table 2 to 5 show that image measurement must be carefully measured to obtain the precise measurement value. Using computer vision, the determination of the egg mass is dependent on a measurement taken from the image. Once the computed measurement value is far from the exact value, it affects the determination of the eggs' mass. Indeed, a low-cost webcam could be used as a replacement for weighing regarding determining the egg's mass with the aid of the right image processing and analysis algorithm.

With the 96.31% accuracy, this study could greatly be an alternative way in the chicken egg weight estimation method especially in large-scale poultry farms in the Philippines to minimize human interaction during the process as well as to save time and energy.

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