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Computer vision system in measurement of the volume and mass of egg using the disc method

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Abstract. One important process in egg production is the sorting process to determine the grade of the egg. The volume and mass of the egg are the factors needed in this sorting process. But the conventional way to measure egg volume and mass can damage egg and takes a long time. This paper proposes a Computer Vision System (CVS) to measure egg volume and mass quickly, accurately, precisely without damaging the egg. The disc method is a method used to calculate the volume of an object with a circular cross-section such as an egg. CVS was designed to calculate the volume using the disc method and calculate the egg mass using density and regression models, based on images captured in real-time or images that have been captured previously. The validation process is carried out using 50 egg samples by comparing results from the proposed method with manual measurements. To compare the time needed by CVS and manual measurement, an average test was used. To test the output accuracy of the volume and mass of egg, relative absolute error, ANOVA test, and correlation test were used. Whereas to test the output precision, the coefficient of variation was used. Based on the results of the testing conducted, CVS in the proposed method successfully measuring the volume and mass of egg quickly, accurately, precisely, without damaging the egg.

1. Introduction

Egg volume and mass are important factors in the egg production process. One process that uses volume and mass of the eggs as its criteria is the sorting process. Because of the importance of knowing the volume and mass of eggs, the calculation method used must be precise and efficient. One method commonly used to measure egg volume is the water displacement method, where the volume of spilled water is the same as the volume of eggs put into it. But this method is considered to be less accurate, can damage the eggs, and takes a long time [1]. The using of the computer vision system (CVS) is a better alternative to the existing manual method. Computer Vision System (CVS) can measure accurate, precise, quick, and non-destructive egg volume [2]. To measure the volume of eggs, the method proposed used is a two-dimensional CVS, where the camera will capture the cross-sectional image of the egg. Assuming that eggs are an axisymmetric object, the egg volume can be calculated by rotating the cross-section of an egg around its long axis [3]. We can then use various methods of calculating the volume of solids of revolution, namely the cone method [4], methods based on the Pappus theorem [5], Simpson's rules [6], and the disc method [7][8]. The disc method assumes that the volume of a solid of revolution is the sum of the volume of all the thin cylinders that made up the object. The disc method used by Bridge et al. [7] to calculate the volume of Florida Scrub-Jay bird eggs. Koc [8] also uses the disc method to calculate the volume of watermelons. The result from a study by Bridge [7] shows that the volume calculation is accurate. However, the CSV system used cannot automatically align the image obtained parallel to the main axis. This will cost extra time for the user to align the egg manually. The system proposed by Koc [8] was less accurate because as the size of the watermelon increased, the image processing method overestimated the volume. This was because of the change in distance between the camera and the watermelon surface. Although the distance between the camera and the surface where the object lays was constant, the distance between the watermelon surface and the camera reduced with increasing watermelon size.

Mass has a very close relationship with volume. The information about egg's mass was not only used in the grading process but was also used to determine egg-yolk to egg ratio, eggshell thickness, and egg hatchability [9]. For egg mass calculations, if the egg volume is known, the egg mass can be obtained from multiplying the volume and density of eggs [5]. In addition, estimation of egg mass can also be done using a linear regression model [9]. This system uses diameter data obtained from digital image processing to estimate the mass of "White Leghorn Line" chicken eggs.

A similar system that has been developed, there is no system that can calculate the volume and mass of objects simultaneously. This study aims to propose a 2D CVS for predicting the volume and mass of egg using the disc method from the image of the egg. The proposed CSV system can automatically align the image obtained parallel to the main axis. The rest of the paper is organized as follow, section 2 explains the proposed computer vision system. The experimental results and discussion are provided in Section 3. The conclusion is explained in Section 4.

2. Proposed computer vision system

Computer Vision System proposed consists of hardware part and software apart. Hardware in the system is mainly used to take a picture of the egg. Software in the system is used to process the image captured, and perform mathematical calculations to find the volume and mass of the eggs.

2.1. Hardware part

The hardware consists of a camera, LED lighting, black background, and a computer to operate the software, as can be seen in Figure 1. The camera used in this system is a portable webcam "Logitech C170" with a resolution of 5 MP and connected to a computer via a USB cable. This webcam is also equipped with a clamp, making it easier to place. The webcam is placed 30 cm above the egg, with lighting coming from a 5 watts LED lights placed 40 cm above the webcam. The system uses dark-colored cotton fabric. This cover cloth serves to block light from outside the system during the image capture process.

2.2. Software part

The processing phase consists of image capture, initial processing, segmentation, opening-closing, rotation, extracting the size of the egg object, volume calculation using the disc method, and mass calculation.

1. Image Capture. The image capture process is carried out using a portable webcam placed right above the image. The captured image has an RGB color space and is then stored on the hard drive in jpg format with a size of 640 × 480 pixels.

2. Initial processing. Initial processing begins with the color transformation of the image from the RGB color space to the gray scale. The filtering process is done using a Gaussian filter with a 7x7 kernel size, aims to clear the image of existing noise.

3. Segmentation. The segmentation process separates an object from the background. This process begins with the search for the Threshold (T) value automatically. Pixels in gray scale images that have an intensity greater than T will be recognized as objects (white) with binary value 1, otherwise, it will be recognized as a background (black) with binary value 0.

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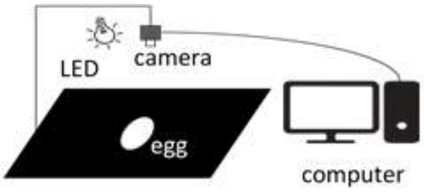

Figure 1. Hardware used in CVS

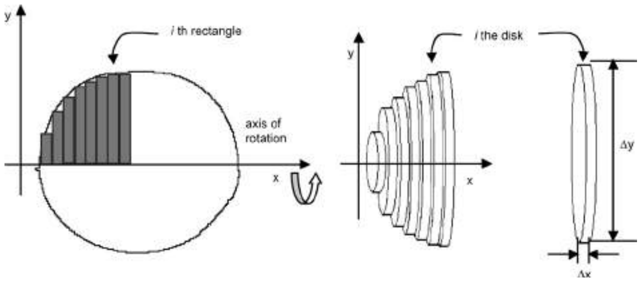

Figure 2a. Cross-section of the object divided into n rectangles; b: cylindrical rotation results on the x-axis

4. Opening-closing. An opening-closing process is performed to remove white spots on the background and black dots on the foreground.
5. Rotation. An image that was not aligned properly will be rotated until its axis parallel to the x or y-axis.
6. Feature extraction. This process aims to find the major axis and the minor axis of the egg. First, we need to locate the leftmost pixel, the rightmost pixel, the topmost pixel, and the lowest pixel of the egg object in the image. The location of the leftmost pixel can be found by scanning the image from the leftmost column (x=0) to the right until the first white pixel found. This will be x_l. The position of the rightmost pixel (x_r), the topmost pixel (y_t), and the lowest pixel (y_l) can be found by similar fashion. The length of the x-axis (Δx) is the difference between x_r and x_l. The length of the y-axis (Δy) is the difference between y_t and y_l. The major axis is the longest between Δx and Δy.
7. Volume measurement. After the length of the major axis and the minor axis of the egg are known, the calculation of volume using the disc method. Volume measurement can be obtained by dividing the cross-section of the object above the major axis into n rectangles with width Δx of 1 pixel and length ½ Δyi with i = 1, 2, 3, ..., n as shown in Figure 2a. Then the rectangles are rotated around the x-axis to produce a cylinder with a height of Δx and a cylinder radius of ½ Δyi as shown in Figure 2b.
The volume of egg (V) can be calculated using Eq. 1, with a k scale factor that can be calculated from the ratio of the object length in cm to the object length in pixels (from the image captured by the camera). In this experiment, the scale factor value k obtained from the average scale factor of five randomly selected samples.

$$V = \frac{\pi}{4} k^3 \sum_{i=1}^{n} (\Delta y_i)^2 \quad (1)$$

8. Mass measurement. Mass measurement is done using two methods, namely, using density and linear regression models. Density is a measurement of mass per unit volume of matter. The mass of eggs (m) was determined using volume (V) and density (ρ) by Eq. 2,

$$m = V * \rho \quad (2)$$

Linear regression is a statistical model that serves to predict the value of non-dependent variables (y) based on independent variables (x) (Franklin and Haribaran, 1994). Eq. 3 represents the common equation of linear regression.

$$y = a + bx \quad (3)$$

From 20 randomly selected egg samples, the density is found to be 1.07 gr/ml, and the regression model is

$$y = 7.3148 + 0.448\,x \quad (4)$$

3. Result and discussion

The validation process of the proposed method is carried out using 50 egg samples from 9 different angles (0°, 30°, 45°, 60°, 90°, 120°, 135°, 150°, and 180°). The result of the proposed method will be compared by manual measurement using water displacement for volume and using digital scales for mass.

3.1. Average Test

The average measurement from 9 different angles, the average of measurement from the experiment, and the time needed by the proposed method will be compared with manual measurements, as shown in Table 1.

Table 1. The average measurement result

Angle	Volume(ml)	Mass (gr)-density	Mass (gr)-regression	Time (ms)
0°	57.79	61.85	61.91	311.59
30°	57.44	61.48	61.58	315.03
45°	57.11	61.13	61.27	312.52
60°	56.75	60.74	60.93	312.09
90°	56.49	60.46	60.69	316.14
120°	56.50	60.48	60.70	318.5
135°	56.54	60.52	60.74	312.22
150°	56.79	60.79	60.97	313.68
180°	56.99	61.00	61.16	319.52
Average measurement of CVS	56.93	60.94	61.11	314.59
Manual measurement	57.87	61.62	61.62	47962.8

As can be seen in Table 1, the results obtained from the proposed method are very close to the results obtained from manual measurement, with differences less than 1.62% in volume and less than 1.1% in mass on average. The average time to measure the volume and mass of the egg using CVS takes 314.59 ms. This is much faster than the time needed manual measurement of 47962.8 ms. This proves that using CVS to measure egg volume and mass can be done more quickly without damaging the egg.

3.2. Accuration Test

To test the accuracy of the result of the volume and mass of egg measurement using CVS, the relative absolute error, ANNOVA test, and correlation test were used.

3.2.1. Relative absolute error test. The absolute error used in this experiment is the magnitude of the difference between the manual measurement value and the measurement value by CVS. The percent error is the relative error expressed in term of per 100, by the following equation:

$$Relative\ absolute\ error = \frac{|manual\ measurement - measurement\ by\ CVS|}{manual\ measurement} * 100\% \qquad (5)$$

The relative absolute error test results for this experiment are shown in Figure 3. An experimental result is said to be accurate if it yields a relatively small absolute error value. Based on the experimental results obtained the absolute relative error value is <5%. This proves that the proposed method is accurate.

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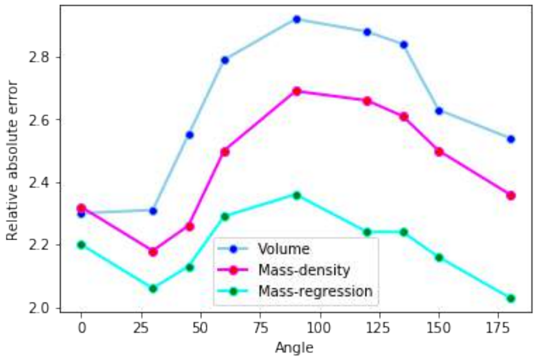

Figure 3. The relative absolute error result

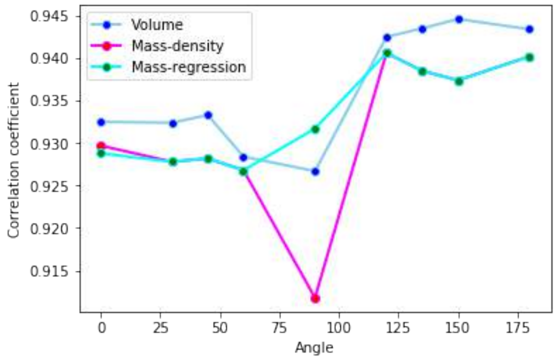

Figure 4. The correlation coefficient result

3.2.2. Correlation test. Correlation is a method of statistical analysis used to measure relationships between variables using a value called the correlation coefficient (R). Two data are said to have a relationship if they have R^2 values that are close to 1. The result of the correlation test in this experiment shown as in Figure 4. All the result of this experiment is close to 1. Thus, this proves that data from proposed method calculations have a relationship with manual data measurement.

3.2.3. Anova test. Anova is a statistical method used to compare the mean of several populations (usually more than 2 populations)[10]. The hypothesis used in ANOVA in this study is:
H0: $\mu_1 = \mu_2 = ... = \mu_{10}$
H1: at least two of the means are not equal
Where μ_1 to μ_9 are average measurements from 9 different angles and μ_{10} is manual measurement as shown in Table 1. To test the hypothesis, use the calculation of the f value using Eq. 6, where MK_k is mean square between populations and MK_d is mean square values within population:

$$f = \frac{M_K}{MK_d} \quad (6)$$

H0 is rejected significantly α if the value f> fα, the value of fα can be seen in the distribution table F. The results of Anova test in this experiment are shown in Table 2.

Table 2. The Anova test result

	Volume	Mass-density	Mass-regresion
f	0.357	0.294	0.272
Significant	0.955	0.976	0.982

The significant value of the Anova test for volume is 0.955, for the mass data density method is 0.976 and for linear regression method is 0.982, so it can be concluded that H0 failed to be rejected. It proves that the mean square values of measured and calculated results are equal or not different. Thus the proposed method is accurate.

3.3. Precision Test
The coefficient of variation is useful to see the distribution of data from the calculated average if the percentage of data distribution is small (<1%) it can be stated that the data is precise. The coefficient of variation (CV) is the comparison between standard deviation (s) and the average value $\bar{x}$ expressed in percentage. The coefficient of variation is expressed by the formula,

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$$CV = \frac{s}{\bar{x}} * 100\% \tag{7}$$

The overall value of the CV of the proposed method can be seen in Figure 5. Based on the above equation, the CV value for all data measurement is <1%, so it can be stated that the volume and mass data resulted from this method are precise.

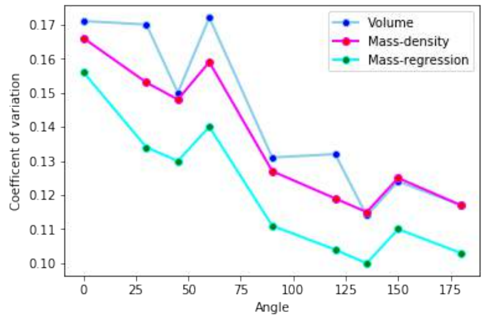

Figure 5. The coefficient of variation result

4. Conclusion

This study proposes a 2D CVS for predicting the volume and mass of an egg using the disc method from the image of an egg. The proposed method has been tested using 50 egg samples from 9 different angles (0°, 30°, 45°, 60°, 90°, 120°, 135°, 150°, 180°). The difference in the orientation of the angle of the egg used turned out to yield similar results. Based on the results of the experiments, CVS in the proposed method successfully measuring the volume and mass of eggs quickly, accurately, precisely, and without damaging the egg. The next study will be to develop CVS to calculate the volume and mass of several eggs simultaneously.

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Preface

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Preface

Welcome Remarks,
Chair of the Steering Committee

It is a great pleasure to welcome all of you to Bali and to the International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand. The first InCITE has been successfully held in Bali, Indonesia in 2017. We are very delighted to host the second InCITE here in Bali, Indonesia again.

There are more than 75 presentations in this conference. We welcome leading experts not only from Indonesia, but also from different parts of the world. The experts will share the knowledge and experiences in the fields of informatics, technology, science, and engineering. The main theme of this conference is **Enhancing Engineering Innovation Towards A Greener Future** in response to several world challenges including sustainable development, global convergence of information and communications technologies, climate change and global warming as well as the depletion of unrenewable natural resources. We hope this conference will provide you a good opportunity to get to know each other better and consolidate bonds of friendship and mutual trust.

We would like to express our sincere gratitude to the Keynote and Plenary speakers, International Scientific Committee, Steering Committee, and Organising Committee for their huge efforts to make this conference successful.

Thank you all for your support and attendance at InCITE 2019. Please enjoy the conference and Bali !

Asst. Prof. Djuwari, Ph.D.

Preface

Welcome Remarks,
Chair of The Organizing Committee

Welcome to Bali, Indonesia to all delegates and presenters. It is my pleasure and privilege to welcome all of you to the 2nd (second) International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand.

InCITE 2019 has received more than 75 papers to be presented in this conference. All papers represent four following parallel clusters: Green Design and Innovation, Green Manufacturing and Green Processes, Power System and Green Energy Management, and The Role of IT in Innovation Enhancement. Each cluster supports the main theme of the conference, which is **Enhancing Engineering Innovation Towards A Greener Future.** The engineering innovation is the key to increase our awareness in maintaining the sustainable growth and development in the world.

The Organising Committee of InCITE 2019 would like to express our sincere gratitude for the tremendous supports and contributions from many parties. The supports from The Faculty of Engineering of UBAYA, keynote and plenary speakers, our International Scientific Committee, the Steering and Organising Committees are really acknowledged.

The last but not the least, thank you for your supports, enjoy the conference and we hope through this meeting all of you can extend your networks and collaborations.

Asst. Prof. Putu Doddy Sutrisna, Ph.D.

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