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# Computer vision system for egg volume prediction using backpropagation neural network

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**Abstract.** Volume is one of considered aspects in egg sorting process. A rapid and accurate volume measurement method is needed to develop an egg sorting system. Computer vision system (CVS) provides a promising solution for volume measurement problem. Artificial neural network (ANN) has been used to predict the volume of egg in several CVSs. However, volume prediction from ANN could have less accuracy due to inappropriate input features or inappropriate ANN structure. This paper proposes a CVS for predicting the volume of egg using ANN. The CVS acquired an image of egg from top view and then processed the image to extract its 1D and 2 D size features. The features were used as input for ANN in predicting the volume of egg. The experiment results show that the proposed CSV can predict the volume of egg with a good accuracy and less computation time.

## 1. Introduction

Indonesia is one of the top egg producing countries in the world. According to the data from Directorate General of Livestock, Ministry of Agriculture, Republic of Indonesia, Indonesia produced egg at about 1.43 billion kilograms in 2016 ([http://www.pertanian.go.id/ap\\_pages/mod/datanak](http://www.pertanian.go.id/ap_pages/mod/datanak)). The huge egg production should be followed by a rapid sorting system. Egg sorting is a process to classify egg based on internal and external qualities. There are several aspects used for assessing the quality of egg. Amongst the aspects is volume [1].

The use of computer vision system (CVS) is an appropriate solution for measuring the volume of egg. Several CVSs have been proposed for measuring the volume of egg, including 2D CVS and 3D CVS [2]. Although 3D CVS has a high accuracy, as proposed by Siswanto et al. [3], this system requires a high computational cost, due to the number of processed image. Soltani et al. [1] have proposed a 2D CVS to predict the volume of egg based on pappus theorem and artificial neural network (ANN). The best prediction was achieved by using ANN with 28 neurons in hidden layer. In predicting the volume of egg using ANN, Soltani et al. [1] used two features, the major and minor diameters of egg, as the input of ANN. By using only this two features, ANN may produce inaccurate prediction. This is because two eggs, with the same major and minor diameters but different cross section area, may have different volume. Gonzalez et al. [4] have proposed a 2D CVS to estimate the mass and volume of passion fruit using ANN combined with Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA). Color, texture, size, and shape were used to define a model for estimating mass and volume. Although the system used many features and used combination of LDA, PCA, and ANN to estimate volume, the system achieved only 73% in terms of the correlation



coefficient, with a typical error of 31.58% for testing data. This result could be caused by the fact that the proposed CVS used inappropriate input features or inappropriate ANN structure in volume estimation.

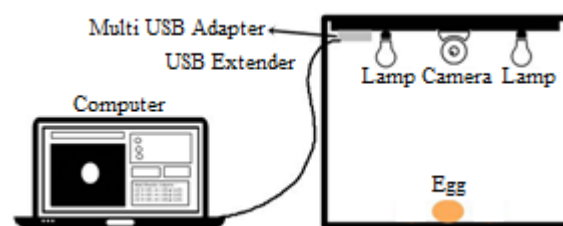
ANN is a nonlinear model that mimics the biological nervous system. It has been widely used to solve various classification and prediction problems [5]. The performance of ANN is strongly related with input features and its structure [6]. One dimensional and 2D sizes of egg, including length, width, area, and perimeter, are strongly related to the volume of egg. In addition, 1D and 2D sizes of egg can be easily extracted from the image of egg. Therefore, there is a need to investigate the use of 1D and 2D sizes as input features for ANN in predicting the volume of egg. Furthermore the appropriate structure of ANN in predicting the volume of egg also needs to be investigated. This paper aims to propose a 2D CVS for predicting the volume of egg using ANN based on 1D and 2D sizes extracted from the image of egg. The rest of the paper is organized as follow. Section 2 explains the detail of proposed CVS. Section 3 describes samples and method used in validation. The experimental results and discussion are provided in Section 4. Conclusion is drawn in Section 5.

## 2. Proposed computer vision system

The proposed CVS acquired the image of measured egg one by one. The image was then processed to produce a binary image. Several features were extracted from the binary image, including length, width, area, and perimeter. The features were used as the input of ANN to predict the volume of egg. The system consisted of hardware and software, designed to facilitate all steps in egg volume prediction. The following subsections describe the detail of hardware and software for the proposed CVS.

### 2.1. Hardware

The hardware consisted of a camera, illumination sources, a computer, a multi USB adapter, a USB extender cable and a container box. Figure 1 shows the configuration of the proposed CVS hardware. The camera was used to acquire the image of measured egg. The proposed CVS employed Logitech® HD Webcam c270h. Two LED lamps were used as illumination sources. The camera and the lamps were connected to the multi USB adapter which was connected to the computer using the USB extender cable. An Intel® Core™ i3 3217U Processor with Windows 7 Ultimate 64 bit operating system and 4 GB RAM was used in the proposed CVS. The camera, the lamps, and the measured eggs were contained in the container box.



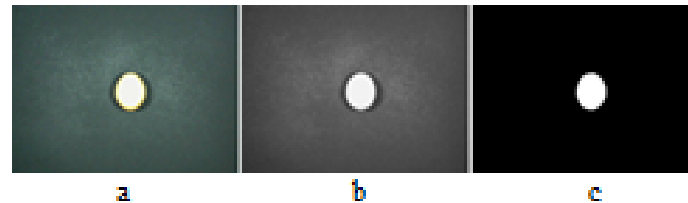
**Figure 1.** The configuration the proposed CVS hardware.

### 2.2. Software

The software was developed to control the camera, to process the acquired image, and to predict the volume of measured eggs. It consisted of several steps including image acquisition, pre-processing, segmentation, features extraction, and volume prediction. The software was implemented using C# in Visual Studio 2010 IDE and library Emgu CV 2.3.10, a cross platform .Net wrapper to the Open CV image processing library. The following subsections explain the steps of the software.

**2.2.1. Image acquisition.** To predict the volume of measured egg, the proposed CVS used an image as input either from the camera or from a file. The camera captured the image of measured egg from top

view in a black background. The background was chosen to make the segmentation step able to be easily performed. The image was acquired in RGB (Red Green Blue) color space. The dimension of the image was  $640 \times 480$  pixels with resolution 96 dpi in both vertical and horizontal directions. During image acquisition, the measured egg was located in the bottom of container box, in any position and any orientation as long as the whole of egg can be captured. The system also had facility for saving the image to a JPEG file. The file would be used for training neural network or could be used to predict the volume of egg containing in the image. The examples of acquired image can be seen in Figure 2 (a).

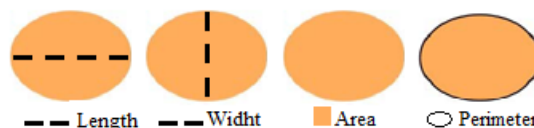


**Figure 2.** The examples of (a) acquired image, (b) pre-processing result, and (c) segmentation result.

**2.2.2. Pre-processing.** In this step, the acquired image was firstly converted to a grayscale image. The intensity of a pixel in the grayscale image was obtained from the R, G, and B intensities of the pixel in the RGB image [7]. A  $5 \times 5$  Gaussian filter was then applied to the grayscale image to increase the quality of image by means of noise reducing [8]. The examples of pre-processing result can be seen in Figure 2 (b).

**2.2.3. Segmentation.** Segmentation aims to separate an object from its background in the grayscale image. The proposed CVS employed automatic thresholding to perform segmentation. A threshold value  $T$  was automatically determined using a simple iteration, as explained in Gonzalez and Woods [8]. The result of this step is a binary image. Any pixel in the grayscale image with grey level value greater than  $T$  was transformed into white pixel in the binary image, and any pixel in the grayscale image with grey level value less than or equal  $T$  was transformed into black pixel in the binary image. The examples of segmentation result can be seen in Figure 2 (c).

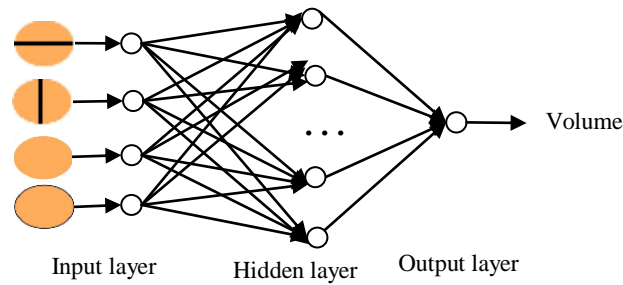
**2.2.4. Features extraction.** Several features were extracted from the binary image. The proposed CVS used 1D and 2D sizes of egg which are strongly related to the volume of egg, to predict volume. The features consisted of length, width, area, and perimeter. Length was defined as the longest distance between two pixels in the boundary of egg. The line between these pixels was considered as major axis. Width is defined as the longest distance between two pixels in the boundary of egg in perpendicular direction to major axis [9]. Area and perimeter are defined as area and perimeter of egg in binary image. By this definition, area and perimeter were measured by counting the number of white pixels in binary image and by counting the number of white pixel in the boundary of egg, respectively [10]. Figure 3 shows the illustration of length, width, area, and perimeter measurements.



**Figure 3.** The illustration of length, width, area, and perimeter measurements

**2.2.5. Volume prediction.** The proposed CVS employed an ANN to predict the volume of egg. The structure of ANN consisted of three layers: an input layer, a hidden layer, and an output layer. The input layer had four neurons, which corresponded to four features extracted from egg image. The

output layer had a neuron, which corresponded to the volume of egg. The number of neuron in the hidden layer was determined empirically from two neurons until seven neurons in an experiment, such that the best structure of neural network was obtained. Mean square error and correlation coefficient between the predicted output and the actual output of ANN were used as criteria to choose the best structure. Figure 4 shows the structure of ANN used to predict the volume of egg.



**Figure 4.** The structure of ANN used to predict the volume of egg.

Sigmoid functions were used as transfer functions both from the input layer to the hidden layer and from the hidden layer to the output layer. The ANN was trained using back propagation algorithm with momentum [11]. All input and output variables were normalized to interval  $[-1, 1]$  before training and testing phases. This normalization aimed to reduce the bias in the model and to speed up the training process [12]. To predict the volume of egg, the predicted output of ANN was transformed to original scale using the inverse of transformation used in normalization.

### 3. Validation

To validate the proposed CVS, an experiment had been performed using 80 samples of egg. The samples were chosen randomly from traditional market in Surabaya Indonesia. To train the ANN, the samples were separated into two sets, one for training set and the rest for testing set. The ratio between training set and testing set was 70:30. The actual volume for every egg was measured using water displacement method for training the ANN and validation process. Once ANN was trained, the volume of each sample was predicted using the proposed CVS. To assess the accuracy of the proposed CVS, the predicted volume and the actual volume of every sample were compared using absolute relative error (ARE). Let  $V_A$  and  $V_P$  be the actual and predicted volumes of every sample, respectively, then ARE was calculated using equation (1).

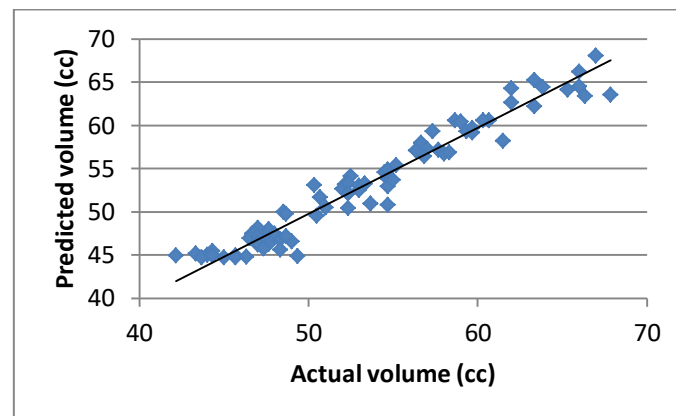
$$ARE = \frac{|V_P - V_A|}{V_A} \times 100\% \quad (1)$$

### 4. Results and discussion

The experiment result show that the best structure of neural network was achieved using three neurons in the hidden layer. By using this structure, the mean square error and correlation coefficient of neural network were 2.3338 and 0.9738 for all samples, respectively. This result shows that the predicted volume of egg is very close and has a strong linear correlation to the actual volume. Therefore, the proposed CVS used the neural network with four neurons in input layer, three neurons in hidden layer, and one neuron in output layer to predict the volume of egg. The correlation between the predicted volume and the actual volume of egg is depicted in Figure 5.

The predicted and actual volumes for all samples are summarized in Table 1. As can be seen in Table 1, mean, standard deviation, minimum, and maximum of predicted volume were close to mean, standard deviation, minimum, and maximum of actual volume. The proposed CVS produced mean ARE of 2.2078 %, for all samples. This result shows that the proposed CVS has a good accuracy in predicting the volume of egg. There were six samples (7.5%) with ARE more than 5%. This could be

because the samples had darker shell color than the other samples. The darker shell color would be caused by some pixels near the boundary of egg recognized as background in segmentation process. To overcome this drawback, a local segmentation, as proposed by [13], can be applied to replace automatic thresholding. For comparison, the volume of each sample was also measured using volume prediction method proposed by [1] and obtained mean square error of 26.1226, correlation coefficient of 0.7281, and mean ARE of 3.5016%. This comparison results show that the proposed method archives better performance than volume prediction method proposed by [1].



**Figure 5.** The correlation between the actual volume and the predicted volume of egg for all samples.

**Table 1.** The summary of volume prediction for all samples.

	Num. of samples	Mean	Std. dev.	Min	Max
Predicted volume (cc)	80	53.0833	6.6110	44.6720	68.0608
Actual volume (cc)	80	53.2979	6.6672	42.1667	67.8333
ARE (%)	80	2.2078	1.8381	0.0013	9.1478

Furthermore, the paired  $t$ -test was performed to show that the mean of predicted volume and actual volume are not significantly different. The test was used because the two volume data come from same sample. The test was performed using a significance level of 0.05 with the hypothesis  $H_0: \mu_1 = \mu_2$  vs.  $H_1: \mu_1 \neq \mu_2$ , where  $\mu_1$  and  $\mu_2$  are the mean of predicted volume and actual volume, respectively. The result of the paired  $t$ -test is shown in Table 2. It can be seen in Table 2 that the paired  $t$ -test resulted  $p$  value of 0.2109. This  $p$  value was less than the significant level 0.05. Therefore,  $H_0$  would be rejected at the level of 0.05 and it can be inferred that the mean of predicted volume and actual volume is not significantly different.

From computation time point of view, the proposed CVS needed 2.636 s for training phase with 56 (70%) training samples. To predict the volume of egg, the computing time of the system was only 0.0156 s per sample on average. This result shows that the proposed CVS can be applied to perform volume measurement for egg sorting in real time production quality inspection.

**Table 2.** The result of paired  $t$ -test.

Paired differences		T	do	p value
Mean	Std. dev.			
-0.2147	1.5221	-1.2614	79	0.2109



## 5. Conclusion

In this paper, a computer vision system for egg volume prediction using artificial neural network is proposed. The system consisted of hardware and software used for image acquisition, image processing, and volume prediction. The image of measured egg was captured from top view and was then processed to extract the features of measured egg, including length, width, area, and perimeter. The features were inputted to neural network for predicting the volume. The experiment result shows that the proposed system achieved absolute relative error of 2.2078% on average compared to the actual volume. Furthermore, the predicted volume had a good linear correlation with the actual volume with correlation coefficient of 0.9738. The result of statistical analysis shows that the means of the predicted volume and the actual volume are not significantly different. For feature research, the proposed system can be extended to measure the volume of other food stuffs such as lemon, orange, and tomato. However, additional features used for predicting the volume might be needed to increase the accuracy.

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