Pig Weight Estimation Using Image Processing and Artificial Neural Networks

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***Abstract*—The objective of this study was to investigate the method for pig weight estimation by using image processing and artificial neural networks. Eighty-eight crossbred pigs (Large White × Landrace × Duroc Jersey) were used. Pigs were individually weighted, measured heart girth and body length. Thereafter, the top-view images of pigs were captured, and the ratio of pig pixels to total area (image) was analyzed by using Python programming. The data was divided into two groups as training set (n=62) and testing set (n=26). The correlation of body weight and heart girth as well as body length and image was determined by Pearson correlation. The training set was used to develop equations of pig weight by regressing analysis and Artificial Neural Networks (ANN). The Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE) were used to measure an error of estimation. The results showed that the high positive correlation with body weight was observed in image, heart girth, and body length (0.930, 0.872 and 0.849, respectively). With regard to regression analysis, the equation including image showed a higher accuracy (R^2 = 0.866) when compared to the equations including heart girth (R^2 = 0.760) or body length (R^2 = 0.721) as well as the equation including both heart girth and body length (R^2 = 0.835). For ANN analysis, the model including image expressed a better fit (R^2 = 0.892) when compared to the equation obtained from regression analysis. Furthermore, ANN analysis showed lower MAD (0.618) and MAPE (6.243) when compared to regression analysis (MAD=0.630 and MAPE=6.410). In conclusion, image processing is a quick method to estimate body weight without casing stress to the pigs. The use of ANN is an alternative method to increase the accuracy of the model for pig weight estimation.**

***Index Terms*—artificial neural networks, body weight, estimation, image processing, pig**

I. Introduction

In commercial pig production, the measuring body weight is one of the most important keys to monitor animal conditions including growth performance and health status. The pig body weight can be used to determine the nutrient requirements, the drug dosages, and the time to market [1]. However, to drive the pigs to a weighing equipment is a time-consuming and labor-intensive. This activity also induce pig to become a stress or injury. Instead, body measurements such as heart girth and body length have been applied to estimate live body weight [2]. The study showed that a high positive correlation was observed between body measurement and pig body weight. Unfortunately, this technique still needs to restrain pig to be the right position, which can cause the stress of the pig. Recently, computer vision using camera image has been introduce to estimate pig body weight [3], [4]. The accuracy of the weight estimation also depends on the prediction models, which have been mostly developed by using regression analysis [2], [5]. However, regression analysis requires a specific mathematical model (e.g. linear, quadratic or non-linear models), which appears to be more limited potential to obtain the target value [6].

Alternatively, Artificial Neural Networks (ANN) are a computational model, which is based on the biological neuron of human brain to respond optimal estimated value [6]. The advantage of ANN has been reported since it does not need mathematical models before prediction when compared with the regression analysis [6]. For livestock animals, ANN have been applied for the prediction of animal growth [6], [7], the estimation of digestible values in full-fat soybeans [8], egg price forecasting [9] and feed forecasting [10]. The ANN was also introduced to estimate pig body weight [11]. The pig images were used to train with corresponding pig body weight, and the results showed that the ANN technique improved the estimation of pig body weight. Likewise, ANN showed a better fit of models with lower errors when compared to regression analysis [6]-[8], [10]. Therefore, the objective of this study was to investigate the method for pig weight estimation by using body measurements in comparison with image processing. Regression analysis and ANN were used to develop the models of pig weight estimation.

II. Materials and Methods

A. Animals and Housing

The experiment was carried out in February to March, 2019. Eighty-eight crossbred pigs (Large White × Landrace × Duroc Jersey) were used. The average body weight was 9.84 ± 2.03 kg. The research unit was equipped with an evaporative cooling system to control the air-temperature at 29-30 °C. The pigs were kept in fully slatted pen (1.6 m^2 floor space per pig). Each pen was furnished with a heating lamp and a low-pressure drinking nipple that allowed free access to water. The pigs were fed *ad libitum* with automatic feeder.

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B. Equipment and Data Collection

The stainless-steel cage (33 × 75 × 51 cm) was designed to put on the digital balance. Each pig was moved into the stainless-steel cage to measure the body weight. Thereafter, body length and heart girth were collected by using a clothing tape. Body length was defined as the length from the base of the neck to the base of the tail, whereas the heart girth was defined as the chest area behind the forelegs [2]. A camera was hold on over a pig at a location covering the stainless-steel cage. The top-view camera images were captured when the pigs had straight posture. The captured images were resized to 1063 × 425 pixels. The segmentation started with binarization and then, followed by morphological operations. The pixels were measured as white and black, and the ratio of pig pixels to total area (image) was analyzed by using Python programming.

C. Data Analysis

The data was divided into two groups as training set (n=62) and testing set (n=26). The training data was used to develop the models of pig weight estimation by using regression analysis and ANN according to Kaewtapee *et al.* [6]. The data were randomized for validation during the training process to prevent overfitting. The estimated values were tested by using the actual body weight from testing set. The correlation coefficient between body weight and heart girth as well as body length and image were determined by Pearson correlation (r) as following model:

$$r = \frac{\sum_{t=1}^{n}(x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_{t=1}^{n}(x_t - \bar{x})^2 \sum_{t=1}^{n}(y_t - \bar{y})^2}}$$

where x_t, y_t are observed values at time t, $\bar{x}$ is mean of x, $\bar{y}$ is mean of y, and n is the number of observations. The testing data was used to estimate the body weight, and to compare with the observed values. The accuracy of each predictive model was determined by R^2 computed as following model:

$$R^2 = 1 - \frac{\sum_{t=1}^{n}(y_t - \hat{y})^2}{\sum_{t=1}^{n}(y_t - \bar{y})^2}$$

where $\hat{y}_t$ is the estimated value. The error measurements were determined by Mean Absolute Deviation (MAD) and Mean Absolute Percentage Error (MAPE) as following models:

$$MAD = \frac{\sum_{t=1}^{n}\left|y_t - \hat{y}_t\right|}{n}$$

$$MAPE = \frac{1}{n}\frac{\sum_{t=1}^{n}\left|y_t - \hat{y}_t\right|}{y_t} \times 100$$

III. Results and Discussion

The correlation coefficient is presented in Table I. The results showed that body weight had a higher positive correlation (P<0.05) with image (r=0.930) when compared to heart girth (r=0.872) and body length (r=0.849).

TABLE I. The Correlation Coefficient (r) of Body Weight, Heart Girth, Body Length and Image

Correlation coefficient (r)	Body weight	Heart girth	Body length
Heart girth	0.872 (P<0.05)		
Body length	0.849 (P<0.05)	0.775 (P<0.05)	
Image	0.930 (P<0.05)	0.800 (P<0.05)	0.835 (P<0.05)

The equations of pig body weight estimation developed by regression analysis are presented as follow:

$$Body\ weight = -9.81 + (0.430 \times Heart\ girth) \quad (1)$$

$$Body\ weight = -4.79 + (0.381 \times Body\ length) \quad (2)$$

$$Body\ weight = -9.71 + (0.264 \times Heart\ girth) + (0.195 \times Body\ length) \quad (3)$$

$$Body\ weight = -1.25 + (0.734 \times Image) \quad (4)$$

The statistical potential of the estimated models is presented in Table II. The equation including image showed a higher accuracy (R^2 = 0.866) when compared to the equations including heart girth (R^2 = 0.760) or body length (R^2 = 0.721) as well as the equation including both heart girth and body length (R^2 = 0.835). For ANN analysis, the model including image expressed a better fit (R^2 = 0.892) when compared to all equations obtained from regression analysis. With regard to image, ANN analysis showed lower MAD (0.618) and MAPE (6.243) when compared to regression analysis (MAD=0.630 and MAPE=6.410).

TABLE II. Statistical Potential of the Estimated Models of Pig Body Weight from Regression Analysis and Artificial Neural Networks

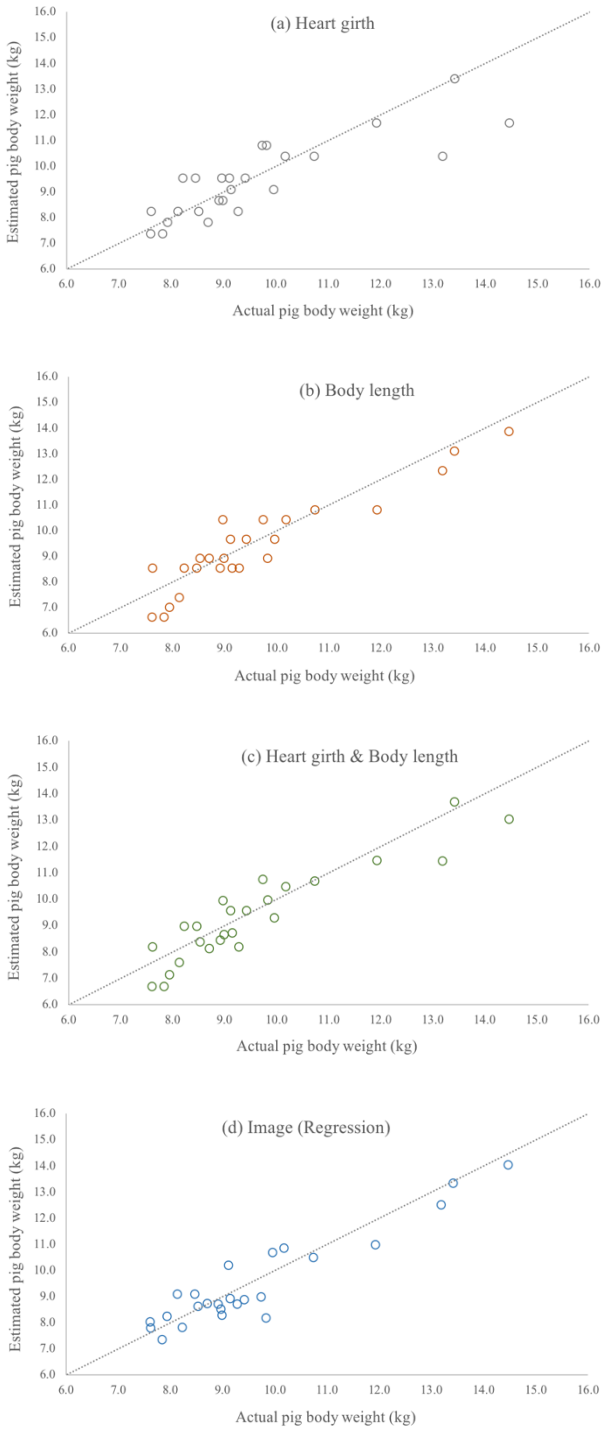
Statistical potential	Regression analysis				Artificial neural networks (ANN)
	Variables				Variable
	Heart girth	Body length	Heart girth & Body length	Image	Image
R^2	0.760	0.721	0.835	0.866	0.892
MAD	0.697	0.614	0.611	0.630	0.618
MAPE	6.826	6.622	6.460	6.410	6.243

MAD = mean absolute deviation; MAPE = mean absolute percentage error

The heart girth and body length were normally used as the parameters to estimate pig body weight due to a strong relationship [12]. As shown in a previous study [13], pig body weight had higher correlation with heart girth when compared to body length. This is in line with

the present study, where the high correlation with body weight was observed in heart girth and body length. However, such relationships could be difference depending on breed, sex, age, position and techniques of body measurement.

The estimated pig body weight obtained by regressing analysis and ANN is shown in Fig. 1a-1e. The model including image developed by ANN (Fig. 1e) showed the better estimated values when compared to equations developed by regression analysis (Fig. 1a-1d).



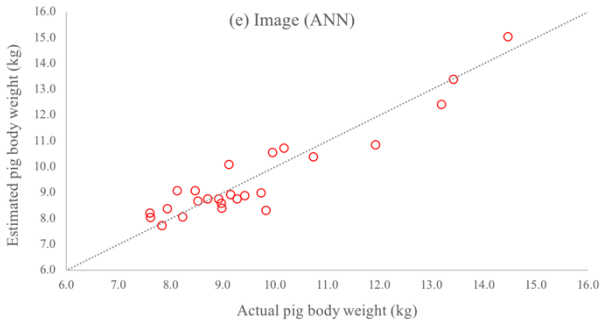


Figure 1. Estimated pig body weight and actual pig body weight were calculated by using data from testing set. The models were developed by regression analysis (a = Heart girth, b = Body length, c = Heart girth & Body length, and d = Image) and artificial neural networks (ANN; e = Image).

Notably, the top-view camera image showed a higher R^2 with lower MAPE for estimated values of pig body weight when compared to regression analysis. As shown in previous studies [3], [4], the digital images have been used successfully to estimate pig body weight. This is in agreement with this study, where image processing increased the accuracy of the model with reducing error measurement. However, the pig shape also affected the pig pixels, resulting in a lower precision of the models. In addition, it did not work on non-straight postures [4].

The better statistical potentials in ANN than regression analysis have been widely reported [6]-[8]. The use of ANN showed the lowest bias with producing a little or no overestimation of the observed body weight of broiler chickens when compared to Gompertz equation [7]. Similar to our previous research [6], where ANN produced more accurate prediction than linear and non-linear regression analysis in growth curve of Cherry Valley ducks, the standardized ileal lysine digestibility in heated full-fat soybeans [8], and soybean meal price forecasting [10]. In the present study, the model including image obtained by ANN also increased R^2 when compared to the model using the same variable obtained by regression analysis. Likewise, Wang *et al.* [11] reported that ANN can be used to approximate the body weight of pigs in an attempt to improve the accuracy of prediction.

IV. Conclusion

In conclusion, image processing is a quick method to estimate body weight without casing stress to the pigs. The ANN may enhance the accuracy of the model for pig weight estimation. Therefore, the application of ANN for prediction model using image processing is an alternative technique to monitor health status and animal welfare for improving commercial pig production.

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