Image Extraction Based on Depth Information for Calf Body Weight Estimation

Naoki Fukuda[1], Takenao Ohkawa[1] , Chikara Ohta[2] , Kenji Oyama[3], Yumi Takaki[1] and Ryo Nishide[4]

[1]Graduate School of System Informatics, Kobe University, Japan

[2]Graduate School of Science, Technology and Innovation, Kobe University, Japan

[3]Food Resources Education and Research Center, Kobe University, Japan

[4]The Center for Data Science Education and Research, Shiga University, Japan

i_l_i123@cs25.scitec.kobe-u.ac.jp, ohkawa@kobe-u.ac.jp, ohta@port.kobe-u.ac.jp, yumi@people.kobe-u.ac.jp, oyama@kobe-u.ac.jp, ryo-nishide@biwako.shiga-u.ac.jp

Abstract

This paper aims to facilitate body weight estimation by using calf's images taken in a loose barn. In our method, the procedures from image extraction of calves to the resultant body weight estimation are automated. The images with a single calf are used for body weight estimation. Most of the images are unusable, as several or none of the calves are included in the images, otherwise, the body parts are not properly extracted due to the calf's posture. In this paper, we propose a method to select only the images appropriate for body weight estimation. First, the information such as the calf's posture, body information and the angle of the calf to the camera are obtained. Then, this information is examined based on a certain threshold to extract only the appropriate images. Depth images are used because they are less affected by the surrounding environments and are considered useful for extracting calf area. The calf area is extracted by using background subtraction with a depth image. The images which meet all criteria are chosen as appropriate images for body weight estimation. Efficiency of the proposed automated method and manual work are compared by MAPE (Mean Absolute Percentage Error) of estimated calf weight. The MAPE by using manually-selected images was 10.34% and that by using proposed method was 13.94%, which yields the difference of 3.6%. From this result, we confirmed that the proposed method for automatically selecting appropriate images for body weight estimation can fairly perform as well as manual selection and can be effective to reduce human effort.

Keywords: Cattle, Calf, Weight estimation, Image processing, Depth camera.

1. Introduction

In general, the calving interval is often used to examine the fertility of beef cattle. Some of the cattle, however, cannot produce healthy and growing calves effectively nor cannot foster calves appropriately. In order to examine the fertility of beef cattle, maternal abilities are also indispensable other than calving interval, and thus, the calf's weight has been used as an indicator of maternal ability for the past decades (Meyer, 1992). Measuring the calf's weight manually, however, burdens farmers. Various studies have been conducted on methods for body weight estimation (Song et al., 2018, Ogata et al., 2011).

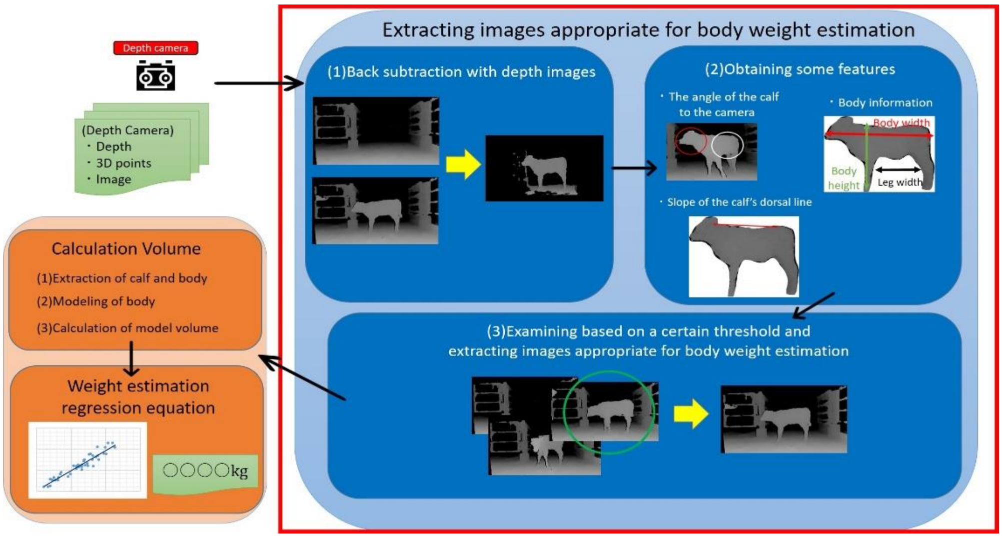

Figure 1. Flow of body weight estimation

We aim to facilitate body weight estimation by proposing a method for body weight estimation by using calf's images taken in a loose barn. In our method, the procedures from image extraction of calves to the resultant body weight estimation are automated. The images with a single calf are used for body weight estimation. Most of the images are unusable, as several or none of the calves are included in the image, otherwise, the body parts are not properly extracted correctly due to the calf's posture. The proposal method utilizes only the images appropriate for body weight estimation by obtaining the information such as the calf's posture, body information and the angle of the calf to the camera and examining them based on a certain threshold.

The rest of this paper is organized as follows. In Section 2, we introduce the flow of body weight estimation and propose the method to select only the images appropriate for body weight estimation. In Section 3, we conduct an experiment applying the proposed method. In Section 4, the effectiveness of the proposed method is evaluated based on the experimental results. Section 5 concludes the paper with some future research directions.

2. METHODOLOGY

2.1 Overview of Image Selection

Fig. 1 shows the flow of body weight estimation system by using calf's images. Body weight estimation consists of three parts; (1) Extracting of calf and body, (2) Modeling of body, and (3) Calculation of model volume (Yamashita et al., 2018, Nishide et al.,2018). Calf's body width, body height and leg width for extracting of calf and body are used. The authors assume that the calf looks sideways to the camera, and the calf's spine is on a perpendicular line to the camera (Left picture of Fig. 2) by using the fact that calf's body is symmetrical around its spine. This line is used for modeling the body, however, the modeling is affected in case that calf's position is oblique to the camera (e.g. Right picture of Fig. 2). For these reasons, only the images appropriate for body weight estimation are selected by using calf's body information and the angle of the calf to the camera (Red frame of Fig. 1).

In a proposed method, the calf area is initially extracted by using background subtraction with depth images. Second, the angle of the calf's position to the camera, calf's body information and the slope of the calf's dorsal line from the root of neck to the hip by using the calf area are obtained. Finally, the images which meet all criteria are chosen as appropriate images for body weight estimation.

2.2 Extracting Calf's Area with Background Subtraction

In this paper, background subtraction is used for extracting a calf, and depth images are used because they are less affected by the surrounding environments and are considered useful for extracting calf area (Fernandez-Sanchez et al., 2013). By using background subtraction, the differences between depth values of calf's input image and a background image are obtained, and calf's area are extracted by comparing with a certain threshold. Fig. 3 shows an example image obtained with background subtraction.

2.3 Calf's Body Information

Horizontal direction is defined as x axis and the vertical direction as y axis as shown in Fig. 4. The longest part of a calf's body in x direction is the part from tip of nose to buttocks defined as *cow_width.* The longest part of a calf's body in y direction is the part from backbone to phalange defined as *cow_height.* When taking pictures of calves, calves are not always standing still but they are sometimes opening their legs or walking. In that case, a ratio between legs width and body width or body height change more drastically than usual. Therefore, we detect both legs and define the differences of both x coordinates as *leg_width*.

2.4 The Angle of Calf Image Shot from Camera

The images used for analysis are taken from the side of calf, however, calf do not always appear perpendicularly to the camera as shown in right picture of Fig. 2. Therefore, oblique calves shot from the camera was detected by using differences between depth values around head and buttocks as shown in Fig. 5.

2.5 The Slope of Calf's Dorsal Line

Calves sometimes raise their buttocks or put their head down as show in Fig. 6. In such cases, calf's body length or body height changes drastically, as the calf's dorsal line from the root of neck to buttocks becomes larger than usual. Therefore, in the proposed method, we also calculate the slope of the calf's dorsal line.

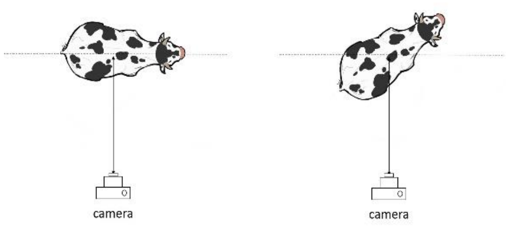

Figure 2. The angle of the calf to the camera

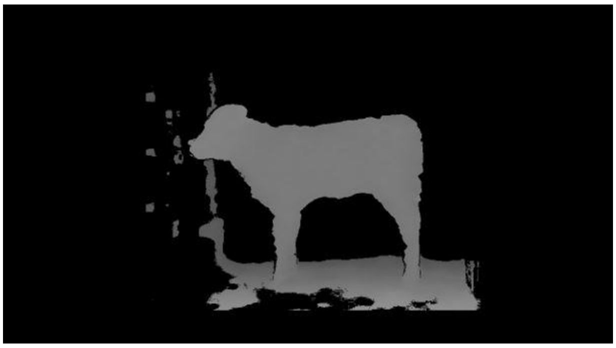

Figure 3. Image obtained with background subtraction

Figure 4. Definition of coordinate system **Figure 5. Example of a calf tilt to the camera**

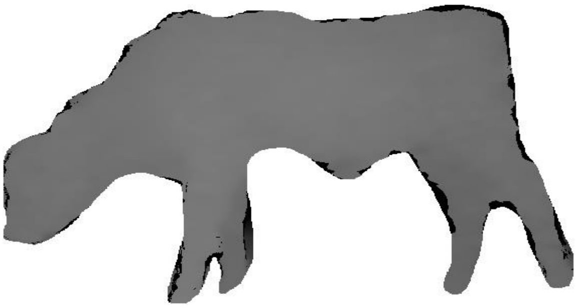

Figure 6. Example of calf lowering its head

3. EXPERIMENT

3.1 Data Set

We conducted experiments on black calves bred at the Food Resources Education and Research Center, Graduate School of Agricultural Science, Kobe University, from newborn to the ones weighing under 100 kg. The camera used for taking pictures is RealSense Depth Camera D415[1] manufactured by Intel. The camera was set to shoot toward the place where only calves walk. When taking pictures, calves were conducted to the front of camera manually by the staff. Data to be used are images of 14 calves in total, which were taken on February 4, 8 and 11, 2019. The number of images is about 40,000. They are all taken within these three days, and include a lot of unstable ones which none of the calves are included in. Only the images appropriate for body weight estimation are selected by using our proposed method. Later, we calculate correlation coefficient and linear regression equation between measured body weight and estimated body weight. When we obtain multiple images of the same calf in same day, we average the result of estimated volume. In addition, we conduct leave-one-out cross validation using obtained data points and calculate estimated weight $\mathrm{W_i^{estimate}}$ from estimated volume V_i. Finally, we calculate error e_i between $\mathrm{W}_i^{\mathrm{estimate}}$ and measured weight $\mathrm{W}_i^{\mathrm{actually}}$, and show the average of error (Mean Absolute Percentage Error MAPE).

$$e_i = \frac{\left|W_i^{estimate} - W_i^{actually}\right|}{W_i^{actually}} \times 100 \tag{3.1}$$

In the experiment, images are selected automatically by using our proposed method and body volume is estimated by using the selected images. Only circle fitting is used when modeling calf body (Yamashita et al., 2018, Nishide et al., 2018). We also estimate body volume using manually-selected images, and compare MAPE when using manually-selected images and the one when using auto-selected images.

3.2 Estimation Result of Volume and Linear Regression Equation

As a result of selecting images from 40,000 by using a proposed method, we obtained 62 usable images. Left graph of Fig. 7 shows the result of body volume estimation using circle fitting. The horizontal axis of the graph is the volume of the obtained model and the vertical axis is the measured weight, as mentioned above.

As a result of selecting images to 40000 ones manually, we obtained 49 ones. Right of Fig. 7 shows the graph of result of body volume estimation using circle fitting. The horizontal axis of the graph is the volume of the obtained model and the vertical axis is the measured weight, as mentioned above.

We conduct leave-one-out cross validation with estimated body volume and measured weight, and take the average of errors for MAPE. We calculate that in each graph. Table 1 shows obtained MAPE and Correlation Coefficient from each graph.

[1]https://www.mouser.com/pdfdocs/Intel_D400_Series_Datasheet.pdf

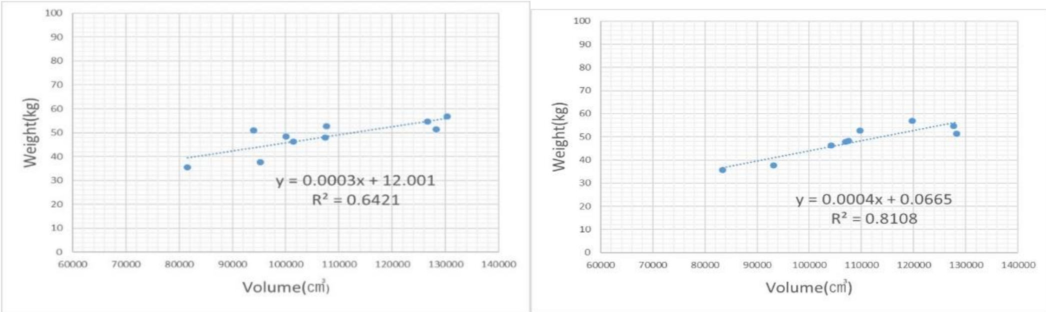

Figure 7. Result of volume calculation (Left: Auto-selected, Right: Manually-selected)

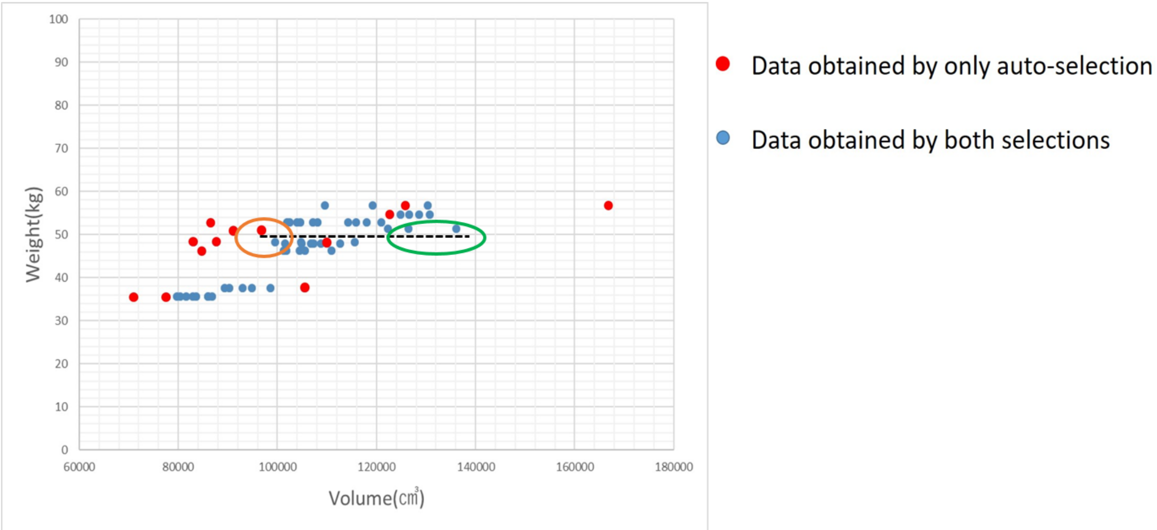

Figure 8. Result of non-averaged volume calculation

Table 1. Mean Absolute Percentage Error(MAPE) and Correlation Coefficient

	MAPE(%)	Correlation Coefficient
Auto-selected	13.94	0.6421
Manually-selected	10.34	0.8108

4. DISCUSSION

Table 1 shows that MAPE obtained when using auto-selected images is greater than the one obtained when using manually-selected images by a slight difference of 3.6%. However, because manually-selected images are selected by manpower, that method can be considered applicable in an ideal environment. Avoiding the effort of manual selection, the proposed method can be a possible solution for automatically selecting images appropriate for body weight estimation. Besides, all 49 manually-selected images are contained in 62 auto-selected images. Therefore, the proposed method has been performed well. However, inappropriate images were extracted by using the proposed method. Hence, inappropriate images must be eliminated. Moreover, the reason why the proposed method did not perform well is mentioned as follows Fig 8. shows all non-averaged data, obtained by both methods. Red points are obtained by only auto-selection and blue ones are obtained by both selections, auto-selection and manually-selection. If the value of weight is equal, then those points refer to the same calf. There are some points which have smaller volume compared with other points with same amount of weight. For example, points circled in orange or green, and a drawn broken line, have same value of weight. However, points circled in orange have smaller volume compared with points circled in green. It is considered that some images which the calf was oblique to the camera were extracted incorrectly. Therefore, width was detected to be shorter than usual, and calf was detected to have a smaller body than usual.

5. Conclusions

In this study, we proposed a method for selecting the images appropriate for body weight estimation by taking calf's pictures with a depth camera and obtaining information from calf's area. Besides, we compared the result of body weight estimation with images obtained by using the proposed method and with the ones obtained manually and verified the precision of the proposed method. As a result, we could at least show the effectiveness of the proposed method.

In the experiment, we could select images appropriate for body weight estimation, but on the other hand, a few images unsuitable for body weight estimation were selected. Thus, we should get rid of the images unsuitable for body weight estimation by using machine learning with auto-selected images or using outlier detection. We plan to further the research on body weight estimation practically by developing the proposed method, so that we don't have to force the calves to stand still in front of the camera.

Acknowledgement

This work was supported by the subsidized projects of Japan Livestock Technology Association, the Council for Information Utilization of Beef Cattle Improvement, the Ministry of Agriculture, Forestry and Fisheries, and JST CREST Grant Number JPMJCR1682, Japan. Note that any implications in this work are not their official opinions.

References

Meyer, K. (1992) 'Variance components due to direct and maternal effects for growth traits of Australian beef cattle', Livestock Production Science, Vol.31, pp.179-204.

Song, X., Bokkers, E. A. M., Tol, P.P.J. van der., Groot Koerkamp, P. W. G. and Mourik, S. van. (2018) 'Automated body weight prediction of dairy cows using 3-dimensional vision', Journal of Daily Science, Volume 101, Issue 5, May, pp.4448-4459.

Ogata, M., Nakahashi, Y., Shibuya, R., and Kuchida, K. (2011) 'Possibility and its precision of body weight prediction by image analysis method for Japanese Black calves', Research Bulletin Obihiro University, 32, 14–19.

Yamashita, A., Ohkawa, T., Oyama, K., Ohta, C., Nishide, R. and Honda, T. (2018) 'Calf Weight Estimation with Stereo Camera Using Three-Dimensional Successive Cylindrical Model', Journal of the Institute of Industrial Applications Engineers, Vol.6, pp.39-46.

Nishide, R., Yamashita, A., Takaki, Y., Ohta, C., Oyama, K. and Ohkawa, T. (2018) 'Calf Robust Weight Estimation Using 3D Contiguous Cylindrical Model and Directional Orientation from Stereo Images', SoICT '18, December 6-7, Da Nang City, Viet Nam.

Fernandez-Sanchez, E. J., Diaz, J., and Ros, E. (2013) 'Background Subtraction Based on Color and Depth Using Active Sensors', Sensors, 13, 8895–8915.