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Research Paper

Evaluation of a depth sensor for mass estimation of growing and finishing pigs

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A method of continuously monitoring animal mass would aid producers by ensuring all pigs are gaining mass and would increase the precision of marketing pigs. Therefore, the development of methods for monitoring the physical conditions of animals would improve animal well-being and maximise the profitability of swine production. The objective of this research was to validate the use of depth images in predicting live animal mass. Seven hundred and seventy-two depth images and mass measurements were collected from a population of grow–finish pigs (equally divided between barrows and gilts). Three commercial sire lines (Landrace, Duroc, and Yorkshire) were equally represented. The pigs' volumes were calculated from the depth image. Linear equations were developed to predict mass from volume. Independent equations were developed for both gilts and barrows, each of the three commercial sire lines used, and a global equation for all combined data. Efroymson's algorithm was used to test for differences between the global equation and the two equations for the gilts and barrows and between the three commercial sire lines. The results showed that there was no significant difference between the global equation and the individual equations for barrows and gilts ($p < 0.05$), and the global equation was also no different from individual equations for each of the three sire lines ($p < 0.05$). The global equation was developed to predict mass from a depth sensor with an R^2 of 0.9905. In conclusion, it appears that the depth sensor would be a reasonable approach to continuously monitor pig mass.

1. Introduction

The main objective of most animal production companies is to provide a product that meets the demands of the customer at a price that allows profit. These demands, however, are becoming more well-defined: e.g. the meat industry pays more to producers for animals within a specified range of mass and composition. Another example is the dairy industry, which pays more or less to milk producers according to the quality and composition of the product (Frost et al., 1997).

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The inability of the producer to obtain, with precision and control, the variables that affect the conformation and fat levels of animals can cause the failure to meet the market's demands. Taking into consideration that farms have increased in size, even small changes in production practices can have a major impact on the global income (Kashiha et al., 2014).

Knowledge of the daily variation of the animals' mass in real time would allow producers to improve the animal well-being and production. It would be possible to use this information to improve nutritional management practices, predict and control the mass at slaughter and, potentially, serve as a monitor for disease outbreaks (Brandl & Jorgesen, 1996; Kashiha et al., 2014).

Weighing animals is typically done manually, a process that often requires two workers and can take three to five minutes per animal. This practice can be stressful for both animals and workers, time consuming, and represents an ergonomic risk (Brandl & Jorgesen, 1996).

Therefore, an automated system to determine the animals' mass has the potential to assist producers to classify them to market and minimise the number of pigs marketed outside specification, improving the yield of production. Many attempts have been made to find an alternative to manual weighing.

Essentially, two approaches have been studied: automated weighing systems combined with individual animal identification equipment and indirect determination of mass using the animals' dimensions.

In general, the automatic weighing systems involve direct contact with the animal. They can be used in the form of semi-automatic scales (Smith & Turner, 1974), significantly reducing the time of weighing, in the form of automatic feeders with automatic scale (Ramaekers et al., 1995; Schofield, Whittemore, Green, & Pascual, 2002; Slader & Gregory, 1988), and can be successfully used for individual monitoring of pigs in a herd, reducing the time spent on the process. Problems with this approach involve the presence of more than one animal or other material on the scale during weighing, and material under the feeder, which could generate measures that cannot always be trusted.

The significant correlation between mass and pigs' dimensions has led many authors to study the possibility of estimating body mass using such a relationship (Brandl & Jørgensen, 1996). Some methods of indirect measurement of mass, through pigs' dimensions, using tapes and callipers have been widely used by producers. Although these are faster methods than manual weighing, they still require that the pig is immobilised and they do not provide mass with great accuracy. Alternatively, several authors (Frost et al., 1997; Kashiha et al., 2014; Schofield, 1990; Schofield, Marchant, White, Brand, & Wilson, 1999; Wang, Yang, Winter, & Walker, 2008; Whittemore & Schofield, 2000) have developed techniques for obtaining animals' dimensions from digital images, and this has been shown to be an efficient non-invasive method.

In general, the difficulty with the determination of mass through images is that, to extract the dimensions of the pig, its colour must be different from the colour of the environment. Dark skinned, stained, or dirty pigs make this approach very difficult to automate. In addition to the colour of the animal, the presence of adequate light is critical for this application. Kashiha et al. (2014) found good illumination values within the range of 40–150 lux. Wu et al. (2004) sought to solve this problem by developing a system for capturing images with six high-resolution cameras (3032 × 2028 pixels) and three flash units to obtain the 3D shapes of live pigs. One problem with this approach was the large amount of equipment and the high costs involved, which makes this type of image capture difficult on an industrial scale.

Finally, Kongsro (2014) proposed the use of a Microsoft® Kinect® sensor to obtain depth images. The Kinect® is a sensor that serves as a 3D measurement device and it has been receiving the attention of several authors due to its low cost, reliability and speed of measurement (Smisek, Jancosek, & Pajdla, 2013, pp. 3–25). The Kinect® sensor is a compound device consisting of a digital colour RGB camera, an infrared (IR) emitter, an infrared depth sensor, four microphones, a three-axis accelerometer and a tilt motor (Microsoft®). The sensor provides three images: infrared, colour and depth. The benefit of using a depth sensor instead of a digital camera is that depth sensors are not as prone to effects of lighting or shadows. Kongsro (2014) showed that the volume of the animal obtained through these images was correlated with the mass of Landrace and Duroc boars. This system could estimate the mass of the boars with an error between 4 and 5%. This work leaves the question, would there be a different correlation for barrow or gilts and is there a significant difference between sire-lines?

The objective of this study was to extract pigs' mass data from depth images, using a low-cost depth sensor and test for the effect of commercial sire lines (Duroc, Landrace, and Yorkshire) and sexes (gilts and barrows).

2. Material and methods

The experiment was conducted in a grow-finish building of the U.S. Meat Animal Research Center, from the Agriculture Research Service-ARS of United States Department of Agriculture – USDA (−98.13°W, 40.52°N). Animal mass and digital and depth images were collected from a population of grow-finish pigs at four distinct time points through the grow-finish period. All animal procedures were performed in compliance with federal and institutional regulations regarding proper animal care practices (FASS, 2010).

2.1. Animal specifics

Two hundred and thirty-four grow–finish pigs (equally divided between barrows and gilts) were sampled at each of four approximate ages: 8-, 12-, 16- and 21-weeks old. The pigs represented three commercial lines sire lines (Landrace, Duroc and Yorkshire). The maternal line was a mix of Landrace × Yorkshire; each of the sire lines were equally represented in the sample. Pigs were housed in standard grow-finish type arrangement, with 39 pigs pen^{-1} (0.93 m^2 pig^{-1}), and had *ad libitum* access to feed and water through the growing period.

2.2. Image acquisition

An image acquisition program was developed in MATLAB software, version R2015b to acquire data from a Kinect®

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