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Automatic weight estimation of individual pigs using image analysis

Mohammadamin Kashiha [a,*], Claudia Bahr [a], Sanne Ott [b,c], Christel P.H. Moons [b], Theo A. Niewold [c], Frank O. Ödberg [b], Daniel Berckmans [a]

[a] M3-BIORES – Measure, Model & Manage Bioresponses, Department of Biosystems, KU Leuven, Kasteelpark Arenberg 30, B-3001 Leuven, Belgium
[b] Department of Animal Nutrition, Genetics, Breeding and Ethology, Ghent University, Heidestraat 19, B-9820 Merelbeke, Belgium
[c] Division of Livestock-Nutrition-Quality, Department of Biosystems, KU Leuven, Kasteelpark Arenberg 30, B-3001 Leuven, Belgium

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ABSTRACT

Health is a key element in pig welfare and steady weight gain is considered an indicator of good health and productivity. However, many diseases such as diarrhoea cause a substantial reduction in food intake and weight gain in pigs. Therefore, continuous weight monitoring is an essential method to ensure pigs are in good health. The purpose of this work was to investigate the feasibility of an automated method to estimate weight of individual pigs by using image processing.

This study comprised measurements on four pens of grower pigs, each consisting of 10 pigs. At the start of the experiments, pigs weighed on average 23 ± 4.4 kg (mean ± SD) while at the end their average weight was 45 ± 6.5 kg. Each pen was monitored by a top-view camera. For validation purposes, the experiment was repeated once.

Individual pigs were automatically identified by their unique painting patterns using shape recognition techniques. The weight estimation process developed as follows: First, to localized pigs in the image, an ellipse fitting algorithm was employed. Second, the area the pig occupying in the ellipse was calculated. Finally, the weight of pigs was estimated using dynamic modelling. The developed model was then validated by comparing the estimated weight against manual twice weekly actual weight measurements of each individual pig. In addition, to monitor the weight of pigs individually, the pigs were marked on their back with basic unique paint patterns and were identified automatically using shape recognition techniques. In this way, the weight of each individual pig could be estimated. This method can replace the regular weight measurements on farms that require repeated handling and thereby causing stress to the pigs.

Overall, video imaging of fattening pigs appeared promising for real-time weight and growth monitoring. In this study pig weight could be estimated with an accuracy of 97.5% at group level (error of 0.82 kg) and 96.2% individually (error of 1.23 kg). This result is significant since the existing automated tools currently have a maximum accuracy of 95% (error of 2 kg) in practical setups and 97% (error of 1 kg) in walk-through systems (when pigs are forced to pass a corridor one by one) on average.

Future work should focus on developing specific algorithms to account for the effect of gender and genotype on body surface area and body weight since these factors affect the model parameters for weight estimation.

1. Introduction

At present, there are over 60 billion animals slaughtered yearly for food production (Prakash and Stigler, 2012). The increasing demand for animal products fosters intensive animal husbandry. Market demands force animal producers to increase the number of animals in their flock or herd with fewer resources. To meet the demands of the market while providing sufficient care to the individual animals, farmers might use automatic tools to monitor welfare, health and productivity of their animals (Harris et al., 2001; Botreau et al., 2007; Morris et al., 2012). While today's systems entail efficient use of land and labor, the increased number of animals per farm has resulted in welfare problems because time is too limited to provide individual animal care (HSUS,

* Corresponding author. Tel.: +32 (0) 16 37 70 66; fax: +32 (0) 16 32 14 80.
E-mail addresses: Amin.Kashiha@biw.kuleuven.be (M. Kashiha), Claudia.Bahr1@biw.kuleuven.be (C. Bahr), Sanne.Ott1@biw.kuleuven.be (S. Ott), christel.moons1@ugent.be (C.P.H. Moons), Theo.Niewold1@biw.kuleuven.be (T.A. Niewold), frank.odberg1@ugent.be (F.O. Ödberg), Daniel.Berckmans1@biw.kuleuven.be (D. Berckmans).

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2010). Technologies are presently available that can monitor individual animals automatically 24 h a day. Research reported by (DeShazer et al., 1988) identified over 90 potential applications for image analysis in pig production. Of these, estimation of pig weight was identified as a primary application for the development of image analysis techniques for use in livestock production. Accurate monitoring of weight gain performance and the use of weight data to make effective management decisions is also crucial for efficient pork production. As farms continue to grow in size, even small alterations to production practices can have a large impact on overall profit in grow-finish pig operations (De Lange and Dewey, 2006). Knowledge of daily weight gain would allow producers to optimize nutritional management practices, predict and control shipping weights, and potentially assist in monitoring herd health (Schofield et al., 1999).

Automatic monitoring of animals based on video analysis is a novel approach, which has been applied in various animal species (Burke et al., 2004; Aydin et al., 2010; Venter and Hanekom, 2010; Poursaberi et al., 2010) and which has proven useful to farm managers (DeShazer et al., 1988; Tillett et al., 1997). Individual weight measurement is an important variable in farm management that nonetheless suffers from a number of drawbacks when performed manually. Firstly, utilizing manual scales is labor intensive and requires movement of animals, which can be stressful for both animals and workers. Secondly, mechanical equipment is prone to malfunction as a result of exposure to dirt, dust, moisture and direct contact with animals. Gathering performance data using a manual scale is therefore done sparingly, generally only at the beginning and end of a production period and most often only for a representative subset of animals, and not for every animal (Schofield, 1990). Machine vision-based weighing of pigs is a non-intrusive, fast and accurate approach, which could reduce stress for both the animal and the farmer during the weighing process (Wang et al., 2008). Since slow weight gain can happen for some of the pigs in a pen, it is important to monitor weight for each pig individually. This helps the farmer to check slow-growing pigs and to make appropriate management changes.

Recently, visual image analysis (VIA) has been proposed as a method for real-time and continuous monitoring of pig weight gain performance, thereby allowing quicker detection of problems and more effective management decisions (Marchant et al., 1999). The VIA technique uses aerial-view images of animals provided by cameras to determine body surface dimensions and may be used for real-time monitoring of pig weight. Since video analysis of pigs has numerous other applications (Van der Stuyft et al., 1991; Xin, 1999; Kollis et al., 2007) weight estimation using videos can be an added value for farmers provided they utilize vision technology.

The concepts of relating size and shape to weight are not new to the field of animal science. According to Whittemore and Schofield (2000), Hammond and Brody were already exploring these concepts in the 1930s and 1940s, with Brody making connections between surface area and live body weight (BW). Historically, consideration of size and shape for evaluation of weight was rejected in favor of direct measurement of live BW due to the difficulty in obtaining the required measurements (Whittemore and Schofield, 2000). More recently however, these concepts have been revisited, as advances in technology make it possible to obtain the required size and shape measurements under current pork production practices.

Since 1991, top-view camera imaging has been known as the least disturbing for animals and it produces the most useful data since it is an elegant way to introduce algorithms from research to field implementation (Van der Stuyft et al., 1991). Past research has indicated that the area of the top view of the pig, minus the head and neck is most strongly correlated to BW (Schofield, 1990). Variation in other components has little effect on estimated live BW, and can therefore be inferred based on the size of the animal's body. Camera technology can be used to determine the area of the aerial view of a pig's body. Using information on the relationship between area and BW, VIA systems have been developed and have been found to be accurate enough to estimate live BW within 5% (Schofield, 1990), but to date, this technology has required that pigs were separated from a group for analysis as an individual.

Other researchers previously investigated different approaches to estimate weight of pigs using image analysis. Brandl and Jørgensen (1996) used spline functions to express the relationship between the body area of the pig measured by image analysis and the live weight of the pig. Marchant et al. (1999) developed automated algorithms that could find the plan view outline of pigs in a normal housing situation, measure major body components and predict the weight of the group of pigs at 34 kg with standard errors of 7.3% while using manual weighing to calibrate the system. Schofield et al. (1999) developed prototype imaging systems to record the weight-related areas of pigs by fitting linear regression coefficients. Furthermore, they could log the growth rates of three groups of pigs of three genetic strains to within 5%. Whittemore and Schofield (2000) examined the value of the estimation of size and shape for animal description in relation to nutrient use in breeding sows and growing pigs. Craig and Schinkel (2001) proposed a mixed effects model[1] to estimate pig weight. White et al. (2004) used a VIA system to continuously collect size and shape data of a total of 116 pigs from 25 to 115 kg of weight for three types of pigs and could classify these groups in 64–83% of observations. Wang et al. (2008) developed an image-based walk-through system for pig live weight approximation. They employed an artificial neural network technique to correlate physical features extracted from the walk-through images to pig live weight in order to improve the accuracy of live weight approximation and could estimate pig weight with an average relative error of 3%.

Some suggest that BW and top-view body area have a linear relationship (Marchant et al., 1999; Schofield et al., 1999; White et al., 2004) and use a single linear regression equation to estimate the live BW of animals from the body area based on the interpretation of individual images. Schofield et al. (1999) suggested that different breeds may require different algorithms for BW prediction. Also Fisher et al. (2003) and Green et al. (2003) suggested a need for unique algorithms for specific breeds or lines of pigs. More recently, researchers have been highlighting the benefits of mixed effects models (Schinkel et al., 2009) and justify their argument that mixed effects model is easily adaptable to stochastic modelling. However, despite the advantages of mixed effects models compared to fixed effects models, it is important to note that there is a large amount of variation in the accuracy of different mixed effects models.

In this work, dynamic data based (transfer function: TF) models were used. Such modelling techniques are compact and allow accurate prediction of the time-variant process response, which makes them suitable for model-based predictive monitoring purposes (Aerts et al., 2003).

In this paper, an approach was presented to monitor pig weights in a fully automated way based on continuous image analysis. The hypothesis in this work was that combining TF modelling and top-view pig body area calculation using image processing could lead to a more accurate weight estimation.

[1] Mixed-effects models, like many other types of statistical models, describe a relationship between a response variable and the covariates that have been measured or observed along with the response. For further information reader is referred to Pinheiro and Bates (2000).