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Asphyxia occurrence detection in sows during the farrowing phase by inter-birth interval evaluation

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ABSTRACT

The occurrence of asphyxia in sows during parturition often results in stillbirths and low vitality piglets, thus significantly affecting pig production and animal welfare in terms of piglet mortality. The losses during farrowing can account to a significant loss in a litter, a whole litter or in extreme cases, the loss of the sow. The objective of this study was to develop an infrared depth image sensor-based monitoring system as a surveillance support system for stockmen during the farrowing phase of sows, in an effort to reduce piglet mortality associated with asphyxiation of piglets. Experiments were performed at Jurong Research farm of Nanjing Agricultural University, using a herd of 105 Meishan sows. Data was collected by monitoring the farrowing process of 15 sows housed in farrowing pens. The sows were monitored by video recording for labeling and depth images taken at 10 fpm for automatic system development. Data labeling was based on the timestamps of births of all the piglets in a litter and each piglet vitality score based on the number of times a piglet attempts to stand within the 1st minute after birth. Data labeling was performed 1 h before the start of parturition until 0.5 h after the end of parturition. The depth images were processed to segment the piglets, and a developed parametrized ellipse-fitting algorithm performed piglet detection by multi-ellipse fitting. Piglet count and count tracking were established by the number of fitted ellipses on the image-object shape. Each sequential increment in the piglet count was used to compute the inter-birth interval. The developed model attained a detection accuracy of 0.832 for no piglets and 0.801 for 14 piglets in a range of 0 to 14 piglets in a litter. In piglet counting and count tracking, the model achieved an average accuracy of 0.918 (R2) at an RMSE of 1.225 piglets. For the classification of an asphyxia event, the model indicated an accuracy of 0.863, specificity of 0.921, precision of 0.791, and a sensitivity of 0.723. The developed system can serve as part of Precision Livestock Farming automatic farrowing monitoring system with the aim of detecting the start of parturition, piglet count tracking, and asphyxia occurrence.

1. Introduction

In pig production and breeding, the farrowing phase is a crucial moment that heavily defines farm economics and animal welfare with regards to piglet mortality. The primary causes of losses during farrowing period are stillbirths and piglet crushing among other causes (Leenhouwers et al., 2003; Moustsen et al., 2013; Pedersen et al., 2006).

Earlier studies done by Leenhouwers et al. (2003) have reported that, globally, 0.9–1.2 piglets per litter are stillborn and deaths occurring just after parturition are often due to asphyxiation during the delivery process. Lucia et al. (2002) defined stillborn piglets as those that were apparently normal but died shortly before or during farrowing. Moreover, postmortem examination reports by Randall and Penny (1967) and Carr and Walton (1995) on stillborn piglets, estimated the time of death as during parturition period. Mild or moderate asphyxiation is a normal occurrence at the parturition phase but the level increases in offspring of polytocous species (pigs) which are born later in a litter (Herpin et al., 1996).

There are two types of asphyxiation during farrowing; fetal and prolonged asphyxia. The former results to intrapartum stillbirths while the latter results in piglets with low vitality and not necessarily stillbirth but can result in deaths during and immediately after farrowing (Herpin et al., 1996). The reduction or depletion of oxygen during farrowing results from several causes such as premature rupture of the umbilical cord, infections, piglet birth weight, sow parity, environmental factors and other dam-related factors (Leenhouwers et al., 2003; Lucia et al., 2002). Herpin et al. (1996) investigated the levels of asphyxia during sow parturition by estimating blood average partial

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pressure of carbon dioxide (pCO_2), blood pH and lactate levels. The study established that the degree of asphyxia was directly proportional to both the birth positions in a litter and litter size, and higher in posterior births. Additionally, live born piglets in litters that underwent asphyxia have a lower vitality score and poor adaptability to the extra-uterine life, up to the age of 10 days (Oczak et al., 2016).

Asphyxiation is always predominated by the occurrence of dystocia in sows due to prolonged farrowing or weak uterine contractions which would often require birth assistance to be provided by the stockman (Pastell et al., 2014). To counter the problem of piglet mortality during the farrowing period White et al. (1996) suggested improved farrowing management protocol and by human supervision (Holyoake et al., 1995). Currently, with large-scale pig breeding, human monitoring is not feasible due to the high cost of labor and its susceptibility to negligence. Furthermore, human contact with animals increases the risks of spreading zoonotic diseases (Slingenbergh and Gilbert, 2004). With the present developments in Precision Livestock Farming (PLF) as a stockman support system in livestock management (Berckmans, 2013; Banhazi and Black, 2009), several studies have applied PLF monitoring systems with an attempt to reduce piglet mortality. Manteuffel et al. (2015) reported on the use of light barriers to detect the onset of farrowing phase in sows, Oczak et al. (2015) classified sow nesting behaviors in non-crated farrowing sows by use of accelerometers. Oczak et al. (2016) suggested an automatic piglet counter to determine the number of piglets in a pen. Nonetheless, no studies have reported on the use of PLF to detect the occurrence of asphyxia in pigs.

Stillbirth is positively related to inter-birth variation and litter size but negatively to gestation length (Björkman et al., 2017; Van Dijk et al., 2005). Thus, identification and quantification of these factors can be used as indicators to the occurrence of asphyxia. Considering that litter size is unknown before the end of farrowing, the best indicators would therefore be gestation length and inter-birth duration. This study introduces a novel technique to detect the occurrence of asphyxiation by evaluating and developing a threshold for the inter-birth interval by newborn piglets detection and count tracking in time series depth images taken during the farrowing phase. The main bottlenecks in image analysis involving livestock are often region of interest (ROI) segmentation and background removal. These problems are further complicated by the adhesive behavior of piglets (Lu et al., 2016) and the low contrast between the foreground (FG) and background (BG) (Wongsriworaphon et al., 2015). To solve the problems related to color contrast, Kongsro (2014) suggested the use of infrared (IR) depth sensors to eliminate errors associated with visible light-based sensors. Hence, this study adopted the use of such depth sensor. To accurately detect, count and count track piglets in an image it is fundamental that the adhesive piglets be split before counting.

This proposed system would significantly enhance studies and research work in evaluation and optimization of the design of farrowing facilities based on piglet detection in the determination of inter-birth duration, which will lead to improved animal welfare and maximized production. The objective of this study was to develop an IR image-based monitoring system for the farrowing process in sows, with specific objectives of developing an IR depth image processing algorithm, an efficient piglet detector, splitting of adhesive piglets and counting and count tracking algorithm. The system, when applied in a practical farm scenario, would serve as a PLF system which should provide support to Stockman as an indicator to the occurrence of possible asphyxia during the farrowing phase.

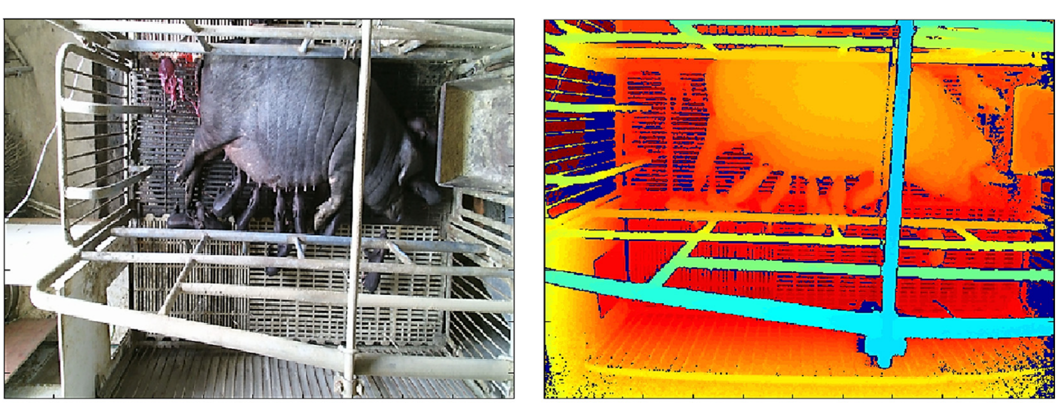
2. Materials and methods

2.1. Experimental setup

2.1.1. Animal housing and data collection

Experiments were conducted between April 2016 and April 2017 at Jurong research farm, Nanjing, Jiangsu Province, China. A total of 15 Meishan sows were included in the experiment. The sows were kept in farrowing pens of about 5 m^2 each. The floor of the pens was partially slatted plastic and partially metallic. Straw racks mountings were positioned in front of the pen near the trough, the racks were filled every morning and replenished whenever empty. The sows were fed twice a day during the experiment period. Water was provided permanently in the troughs via an automatic nipple drinker. The average temperature in the unit was 24 °C with an automatic ventilation system. The sows were introduced into the crates three days before the expected due date of parturition. The experiment period was from 3 h before the first piglet was born until the last piglet was born in the same litter.

Each pen was equipped with one top view 3D Kinect camera for Windows V2 (Microsoft Corp., Washington, USA) and a video camera DS-2CD3T35-13 (HIKVISION) connected to a Turbo digital video recorder HD DVR DS-7200HGH-SH (HIKVISION) to simultaneously monitor the pens. The cameras were installed 2.5 m perpendicularly above the pen floor. The Kinect camera was connected via a USB port to an intel core i5-4500U CPU, 4 GHz, 16 GB physical memory (Intel, Santa Clara, CA, USA), Microsoft Windows 10 PC installed with the Kinect for Windows Software Development Kit (SDK). Images were acquired from the Kinect camera using MATLAB R2016a (The MathWorks Inc., Natick, MA) software with the image acquisition Toolkit (IAT). Depth (for automatic system development) map channel (512 × 424 pixels) was selected in the AIT as shown in Fig. 1(b) for the Kinect camera. The depth images were acquired at 10 fpm and transferred to a 2 TB hard drive for subsequent analysis. The videos (for manual observation, labeling and verification) were recorded at 22 fps MOV format, and to allow for night recording, the video camera was remotely set to night mode. The Fig. 1 shows the digital color image and the corresponding depth image.



(a) (b)

Fig. 1. Captured images (a) digital color image and (b) raw depth image of a sow and piglets in a farrowing pen.

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