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Infrared proximity measurement system development and validation for classifying sow posture

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ABSTRACT. *The rapidly progressing field of precision livestock farming is becoming increasingly dependent on the utilization of camera technology. Integration of camera technology involves substantial intellectual input and computational power to acquire, process, and interpret images in real-time. Further, cameras and the necessary computational power can be cost-prohibitive and subsequently, become a constraint for application in a commercial livestock and poultry production systems. The purpose of this study is to develop an infrared proximity sensor based system to serve as a substitute a camera system to perform real-time monitoring of sow posture in farrowing stalls for a potentially lower cost and computational power. Monitoring sow posture can provide producers an indicator of farrowing and aid in evaluating sow demeanor during lactation. During the development of this system the long range infrared (IR) proximity sensors were individually calibrated, a sow posture algorithm was developed, and the IR-Sow Posture Detection System (IR-SoPoDS) system was evaluated in a commercial setting to a Kinect V2® camera for a range of sow postures. Average accuracy of the sow posture algorithm on the training data was found to be 96%. The overall accuracy of the IR-SoPoDS system across the three sow frame sizes were: 87% (small), 90% (medium), and 89% (large). This IR-SoPoDS system shows a strong promise for further development for sow posture and behavior detection in the farrowing stall environment.*

Keywords. *camera, farrowing, precision livestock farming, swine*

Introduction

Precision livestock farming is of increasing interest for global commercial producers and in particular the swine industry. This interest is rising from the need to improve production and sustainability of swine operations (Norton & Berckmans, 2018). Real-time monitoring of animal behavior and/or posture can offer producers many advantages regarding animal welfare as well as detection of the onset of diseases, breeding cycles and farrowing. Specifically, in the farrowing barn the monitoring of sow posture can be crucial for detecting farrowing and dangerous behaviors that endanger piglets from being laid on, off-feed occurrences, and sow lameness. A popular method for monitoring sow behavior is through machine vision, but this option can become expensive both financially and computationally at the commercial level (Lao et al., 2016; Zheng et al., 2018). To address these technical and financial barriers, the introduction of real-time sow posture monitoring a sensor based system was 1) developed to detector sow posture and 2) compared to a Kinect V2® camera based system.

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Materials and Methods

Experimental Setup and Operation

This sow posture detection system featured a set of three long-range infrared proximity (IR) sensors (Model GP2Y0A02YK0F, Sharp, Osaka, Japan) for measuring the distance to the sow's body. Each sensor was individually calibrated, for a range of 20 to 120 cm with eight points with increasing and decreasing distances. The three IR sensors were mounted on a bracket that attaches to the top of a farrowing stall, with the sensors 15 cm above the top of the stall and equally spaces the sensors by 66 cm across the length of the stall. A system for monitoring two farrowing stalls was developed using an Arduino Pro shield with a data logging shield. The three sensors from each farrowing stall were conditioned with a 16-Bit ADC with a programmable gain. The operation of the system collected samples at a rate of 1 Hz, calculated the distance for each sensor, and determined the posture of the sow using the sow posture algorithm, discussed in the next section.

Algorithm Development

The sow posture algorithm (SPA) was developed using field collected data from both sets of IR sensors. Sows were monitored for thirty minutes during which time each sow's posture was recorded through human observation with the appropriate time stamp. This was completed for 30 min with multiple reps of each posture noted for both stalls on medium frame sows. The SPA was developed as a combination on threshold binning criteria and slopes between the measurements to the sow's body. The SPA was developed through an iterative approach of changing the bins and slope weights until a desirable SPA accuracy on the training data set was obtained. The accuracy was calculated for each posture as the number of true positives and true negatives divided by the total number of positives and negatives. The overall accuracy was calculated as the average of all three posture accuracy's. The SPA ignores IR sensor readings that are below the floor of the stall and requires at least two sensor readings. The SPA discretizes sow posture as "standing", "lying", or "other", other includes sitting, kneeling, and all errors that is, only one valid sensor reading.

Validation

Accuracy of the IR Sow Posture Detection System (IR-SoPoDS) was determined by comparing it to a machine vision system that utilized a Kinect V2® camera attached 2.5 m above the stall (depth and digital images) taking images at 0.5 frames per second (Kinect V2®, Microsoft, Redmond, WA, USA). The Kinect V2® camera utilized an algorithm to determine posture from (Leonard et. al., 2018). Nine different sows, three each for small, medium, and large frame sows, were monitored for a period of 48 to 72 h using both IR-SoPoDS and the Kinect V2® system. For each monitoring period, a 5% sub-sample (1,050 time points) from a continuous 24-hour period (midnight through 11:59pm) was taken for further accuracy analysis. The sub-sample for the three sows of each frame size were pooled and then the accuracy for each posture and overall was determined using the aforementioned accuracy calculation.

Results and Discussion

Calibration and SPA Development

For each IR sensor, a unique individual second-order polynomial calibration equation was developed. No hysteresis was observed for any of the sensors (fig. 1). The SPA development was based on a data set from thirty minutes that post processed for anomalies ending with a data set of 344 instances. The posture accuracy was as follows: 96% (standing), 97% (lying) and 95% (other), with an overall accuracy of 96%.

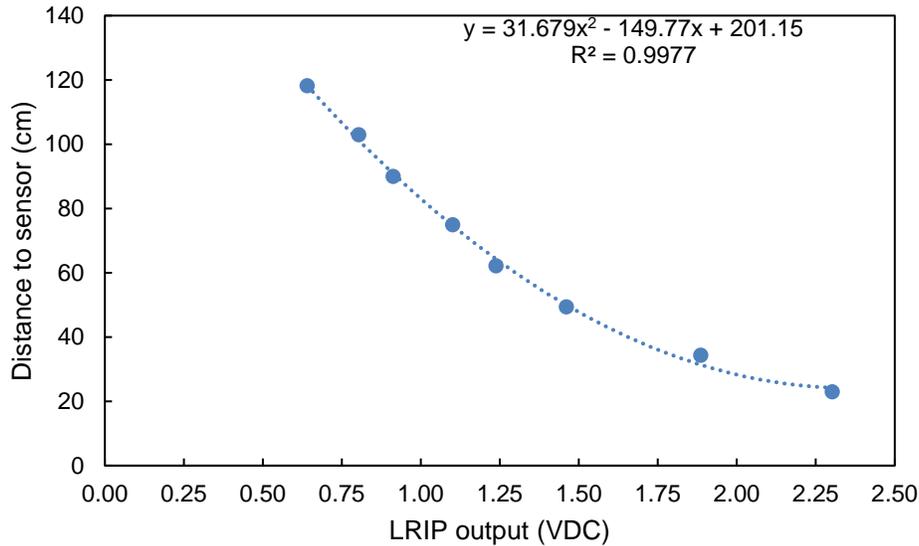


Figure 1 Calibration curve (second order polynomial fit) for one of the IR sensors used in the IR-SoPoDS system.

Validation

The results of the IR-SoPoDS comparison to the Kinect V2® camera system resulted in the following overall accuracies by sow frame size; 87% (small), 90% (medium), and 89% (large). For the sensitivity, specificity, and accuracy by posture across the three frame sizes a similar pattern was observed (table 1). The low sensitivity of the standing and other posture is due to the IR-SoPoDS system correctly identifying true positive conditions for those postures and was influenced by the low occurrence rate of such postures during the day. The low specificity of the IR-SoPoDS for lying shows that the system is not able to correctly identify true negative (lying conditions) under realistic operating conditions. For all three cases, a difference in timestamps that is unavoidable at the millisecond level could be at play resulting in skewed results in the comparison of the IR-SoPoDS to the Kinect V2® system.

Table 1 Sensitivity, specificity, and accuracy by posture and overall for large frame sow posture predicted by the SPA system compared to the Kinect V2®

Posture	Sensitivity	Specificity	Accuracy
Standing	22%	95%	90%
Lying	87%	31%	84%
Other	12%	92%	92%
Overall			89%

Conclusions

The development of the IR-SoPoDS system using IR sensors shows promising results for real-time monitoring of a sow’s posture in a farrowing stall. The IR-SoPoDS was achieved through a low computational cost method in comparison to a camera system. The accuracy of the IR-SoPoDS both during training and field evaluation against the Kinect V2® shows high accuracy in the IR-SoPoDS system. The possibilities for implementing a low-cost, real-time sow posture system in a commercial setting are favorable. Further work with such systems for farrowing detection, sow off-feed, and lameness detection offer commercial producers useful real time data to improve production and wellbeing of the sows.

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Specific instrumentation information details are included herein for detailed clarity of systems used and does not imply endorsement of specific products.

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