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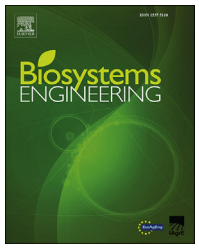

Research Paper

Online warning systems for individual fattening pigs based on their feeding pattern

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For sustainable pork production and maximum pig welfare, all health, welfare and productivity problems in the barn should be detected as early as possible. In this paper, an automated monitoring and warning system is proposed. Based on measurements of the feeding pattern, it is able to generate daily alerts for individual fattening pigs. Using historical data, the following types of warning systems were developed: (1) fixed limits that treat all pigs and all days equally; and (2) time-varying individual limits using the concept of Synergistic Control. These types of limits were constructed either for the number of registrations per pig or the average interval between feeding visits of a pig, leading to four warning systems in total. These warning systems were used to generate alerts during an online validation period. During an entire fattening period, all pigs were individually monitored to establish true alerts, false alerts and missed problems. The best performance was achieved for the Synergistic Control method on the number of registrations, with a sensitivity of 58.0%, specificity of 98.7%, accuracy of 96.7% and precision of 71.1%. Severe problems were detected on average within 1.3 days from the start of the problem. These are promising results that provide a solid basis for the development of a system for individual pigs but further improvements are warranted to make the system more practical.

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Nomenclature

# reg	number of registrations
ADG	average daily gain
ARL_0	in-control average run length
ARL_1	out-of-control average run length
avIVI	average inter-visit interval
EPC	engineering process control
FN	false negative
FP	false positive
LCL	lower control limit
n	number of pig-days
NaN	not a number
RFID	radio frequency identification
SGC	Synergistic Control
SPC	statistical process control
TN	true negative
TP	true positive
UCL	upper control limit

1. Introduction

In pig farming, disease control, animal welfare and production efficiency are important factors to help ensure sustainable pork production and maintain an economically viable farm. Therefore, it is important that health, welfare and productivity problems in the barn are detected and treated early. As the sector intensifies and farms and groups of pigs become larger, visual monitoring of the pigs as a sole tool for problem detection could be suboptimal. Visual monitoring gives only a snapshot-view on the animals appearance (Heitkämper, Schick, & Fritzsche, 2011; van den Heuvel, Hoofs, Binnendijk, Bosma, & Spoolder, 2004) and is often more focused on the group level than the individual level in pig farming. Automated monitoring or Precision Livestock Farming (PLF) (see for example Wathes, Kristensen, Aerts, and Berckmans (2008) and Banhazi et al. (2012)) allows to monitor the livestock online and continuously (Matthews, Miller, Clapp, Plötz, & Kyriazakis, 2016). The automatically gathered measurement data can be transformed into information for the farmer and support the farmer's decision making-process (Cornou & Kristensen, 2013). Using the right techniques, automated monitoring can also be done at the individual pig level, allowing for individual, custom-made care.

Disease, welfare and productivity problems can have an impact on the feeding pattern of a pig (Brown-Brandl, Rohrer, & Eigenberg, 2013; Hart, 1988; Hessel & Van den Weghe, 2011), such as a reduced feeding time or longer intervals between visits. Therefore, a system to measure individual pigs' feeding patterns has recently been developed and validated (Maselyne & Saeys, 2014, Maselyne & Van Nuffel, 2014). Using high frequency (HF) Radio Frequency Identification (RFID), each pig's attendance at the feeder is registered (Maselyne & Saeys, 2014). From these raw data, feeding pattern variables such as the number and duration of feeding visits and pauses between feeding visits of a single pig throughout the day can be calculated (feed intake was not measured) (Maselyne et al., 2016). The present study investigated whether abnormal changes in the feeding pattern of a pig can be detected automatically and used as an (early) indicator for health, welfare and productivity problems.

To detect abnormal changes in the feeding pattern of a pig, fixed limits (the same limit for all pigs and days) can be constructed. However, it has been shown that using a Synergistic Control (SGC) procedure can be a better, alternative option for monitoring livestock production systems (Mertens, Decuypere, De Baerdemaeker, & De Ketelaere, 2011). SGC combines the power of Engineering Process Control (EPC) and Statistical Process Control (SPC) (Montgomery, 2009). In SPC, control limits allow to differentiate abnormal variation from normal variation (due to age, seasonal effects, etc.). The EPC step pre-treats the raw livestock production data to meet the assumptions of the statistical control chart in the SPC step. Thanks to this combination, the online SGC procedure allows to use pig-specific control-limits, which can be updated with every new measurement. Any abnormal variation detected can then be signalled to the farmer as an alert for a specific pig. Promising results have already been obtained with this SGC approach for monitoring process parameters of flocks of laying hens (Mertens et al., 2008, 2009) and milk yield of individual dairy cows for mastitis detection (Huybrechts, Mertens, De Baerdemaeker, De Ketelaere, & Saeys, 2014).

Therefore, the aims of the present study were (1) to develop several warning systems with fixed limits or variable, individual limits on promising variables of the feeding pattern, based on historical data; (2) to validate and compare these warning systems online by comparing the alerts with detailed observations.

2. Materials and methods

2.1. Animals and housing

The pigs were housed in an automatically ventilated barn at the experimental farm of ILVO (Melle, Belgium). They were housed in four identical pens. Each pen measured 4.3 m by 9 m with approximately 40% slatted concrete floor and 60% solid concrete lying area. In addition to natural light, artificial lighting was provided from 7:00 to 21:00. Water was supplied *ad libitum* via nipple drinkers. Dry pelleted feed was automatically supplied using Swing MIDI feeders (Big Dutchman Pig Equipment GmbH, Vechta, Germany). The pigs were fed a commercial feed with 9.3 MJ net energy, 15.50% crude protein and 0.92% lysine *ad libitum*.

The experiments included two batches of fattening pigs; one was used as a '**historical dataset**' to develop the warning systems and then these warning systems were validated online in a '**validation period**'. Experiments were in accordance with EU Directive 2010/63/EU for animal experiments.

2.1.1. Historical data

The warning systems were developed using the data of a fattening period with 152 pigs from January to May 2014. Pen 1 and 4 were filled with 19 barrows and 19 gilts each of about 10 weeks old (Hybrid sow × Piétrain boar; weight equally distributed), and 18 days later also pen 2 and 3 were filled with the same amount of pigs. Starting mass was 24.8 ± 3.9 kg

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