Computers and Electronics in Agriculture 135 (2017) 108–114

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Online detection and localisation of piglet crushing using vocalisation analysis and context data

Christian Manteuffel [a,*], Eberhard Hartung [b], Mariana Schmidt [c], Gundula Hoffmann [c], Peter Christian Schön [a]

[a] Leibniz Institute for Farm Animal Biology, Institute of Behavioural Physiology, Wilhelm-Stahl-Allee 2, 18196 Dummerstorf, Germany
[b] Christian-Albrechts-University Kiel, Institute of Agricultural Engineering, Max-Eyth-Str. 6, 24118 Kiel, Germany
[c] Leibniz Institute for Agricultural Engineering and Bioeconomy, Department of Engineering for Livestock Management, Max-Eyth-Allee 100, 14469 Potsdam, Germany

ARTICLE INFO

Article history:
Received 11 August 2016
Received in revised form 14 November 2016
Accepted 20 December 2016

Keywords:
Online vocalisation analysis
Piglet crushing detection
Active crushing prevention
Precision livestock farming

ABSTRACT

Fatal piglet crushing by the mother sow is a pervasive economic and animal welfare issue in piglet production. To keep the mother sow in a farrowing cage is the established countermeasure. This facility is a compromise that results in an impairment of the sows' welfare to the benefit of her piglets and the farmer. A natural behaviour pattern which is demonstrated by most but not all sows is to free the trapped piglet by a posture change. Promoting this behaviour through aversive stimulations is an alternative approach to reduce piglet mortality. This approach requires an identification and localisation of ongoing piglet trapping in real-time. The present study investigates the online analysis of piglet vocalisation for this purpose. The results show, that trapping related stress articulations are outnumbered by other stress related articulations by a factor of 1:140 in a farrowing compartment with only 4 sows. Theoretical calculations for larger compartments indicate that this ratio becomes even worse due to an increasing influence of vocalisation from neighbouring pens. However, the specificity could be increased to more than 95% and precision to approximately 30% while maintaining a sensitivity of approximately 70% by retrospectively applying context based event filters. This specificity would be sufficient to limit the average number of erroneous trapping detections to one detection per sow within 3 days without a substantial loss of sensitivity. Effective parameters for filtering were the age of the piglets and the sows' body posture history. Calculations with hypothetical spatial event filters showed that this classification performance could be maintained even in much larger farrowing compartments. Combined with an aversive stimulation principle that can be applied to a whole region, this detection technology could be useful to reduce piglet mortality in loose farrowing applications. An already known and effective stimulation principle of this type is floor vibration. Such an active piglet rescue system would allow limiting the impairment of welfare to only those sows that actually crush piglets and to the time when piglets are being crushed.

1. Introduction

Fatal piglet crushing by being overlain by the mother sow is a pervasive economic and animal welfare issue in piglet production (Weber et al., 2006). Lightweight and ill piglets are most prone to crushing, as they are less agile and less vital than their littermates and have less ability to escape risky situations. In addition, they tend to spend more time near the sow, probably as a result of higher nutrient need (Weary et al., 1996b). The crushing risk is increased for large litters as they entail an increased number of lightweight piglets (Weber et al., 2006).

The established countermeasure against piglet crushing is the farrowing cage which creates a safe space for the piglets and supports the sow during posture changes. This facility is usually accompanied by a heated piglet creep area where the piglets can huddle for warmth in some distance from their mother sow. The latter is especially relevant in the first days after farrowing where the piglets have still an underdeveloped thermoregulation (Edwards, 2002). Long term confinement of the sow during lactation is believed to be a severe impairment of animal welfare based on ethological studies (Broom et al., 1995), even if this is not conclusively found in physiological studies (Lawrence et al., 1994). Hence, the farrowing cage is a compromise that results in an impairment of the mother sows' welfare to the benefit of her piglets and the farmer. This impairment currently affects all sows, regardless of whether they actually crush piglets.

* Corresponding author.
E-mail address: christian.manteuffel@fbn-dummerstorf.de (C. Manteuffel).

http://dx.doi.org/10.1016/j.compag.2016.12.017
0168-1699/

To actively prevent piglet crushing, in contrast to the passive principle of the farrowing cage, is less common in practice. A commercial system using air blasts to dislodge piglets underneath the sow during posture changes was studied by Thacker and Barber (1987). Very effective for the reduction of piglet mortality but also labour intensive is the manual farrowing supervision (Kirkden et al., 2013). Experienced personnel are often able to recognise a trapped piglet acoustically. In such a case, a posture change of the mother sow would be stimulated by manually forcing her up. Yet, at least for work safety both methods rely on the farrowing cage to limit the movements of the sow.

Avoiding piglet crushing is part of the natural behaviour repertoire of the sow. Replay studies found 60% (Hutson et al., 1991) to 100% (Cronin and Cropley, 1991) of sows reacting, when a piglet dummy was placed underneath their body and piglet squeals were played. Despite the huge weight difference between sow and piglet, timely posture changes by the sow usually save the piglet. A survival rate of about 95% was found for piglets trapped less than one minute. After being trapped for up to 4 min, still about 33% of the piglets would survive (Weary et al., 1996a).

Not reacting to piglet squeals could be a side effect of a calm behaviour during farrowing which is induced by endogenous opioids and might increase the chance for early colostrum uptake for new born piglets (Jarvis et al., 1999). Also fast posture changes, probably due to physical inability to fully control the movement, might lead to dangerous movements of the sow that crush piglets (Weary et al., 1996a). Other studies discuss individual differences in the innate nursing behaviour of the sows that result in piglet crushing. In addition, this behaviour reduces the maternal effort for the sow and could therefore be intentional (Andersen et al., 2005).

The natural behaviour pattern that is beneficial for the piglets could be enforced by actively stimulating posture changes of non-reacting mother sows. Known stimulations for triggering posture changes in sows are for example:

- Slaps (Hutson et al., 1993)
- Water drops (Hutson et al., 1993)
- Electric shocks (Friend et al., 1989)
- Air blasts (Manteuffel et al., 2014)
- Floor vibration (Manteuffel et al., 2014)

Hence, actively freeing already trapped piglets by stimulating posture changes would be feasible.

It is known that piglets have a repertoire of reliably discriminable vocalisations (Jensen and Algers, 1984). In particular, they use vocalisation to express pain (Weary et al., 1998) and distress (von Borell et al., 2009). This also applies to crushing situations (Illmann et al., 2013). In the present study, the stress monitoring and documentation system (STREMODO) was utilised to identify stress vocalisation expressed by trapped piglets (Schön et al., 2004). However, there are many stressful situations for piglets during the lactation phase. The piglets are treated several times with injections, receive markings and might experience amputations for health management reasons. These management procedures can be considered stressful for the piglets (Noonan et al., 1994) and need to be distinguished from crushing related stress articulation. In addition, vocalisation from neighbouring pens needs to be distinguished from local vocalisation.

The present study investigated whether vocalisation analysis for stress articulation alone is able to detect stress articulation specific to trapping situations. In addition, it investigated which context information would be suited to increase the specificity of the crushing detection and how spatial detection filtering could contribute. Available context information was the age of the piglets, the history of posture changes of the sow and the duration of stress articulation. Spatial filtering was performed by comparing the loudness of signals in combination with directional microphones.

2. Material and methods

For the present study, data from two project phases - the development and experimental phase - were analysed. Both phases entail different animals, housing conditions and recording devices. The development phase was conducted in the experimental pig unit of the Leibniz Institute for Farm Animal Biology (FBN Dummerstorf, Germany) while the experimental phase was conducted in an experimental farrowing compartment of a commercial pig breeding and fattening facility (Schweinzuchtanlage Wiechmann, Germany).

2.1. Development phase

2.1.1. Animals and housing

Altogether, for 22 sows (German Landrace) the farrowing and behaviour of 264 piglets was observed until their 14th day post-partum using audio and video recordings. The sows were housed individually in farrowing crates in groups of 6 on slatted floor in the experimental pig unit of the Leibniz Institute for Farm Animal Biology. No nest building material was provided. The sows ranged between 1st and 6th parity. The piglets were provided with a floor heated creep area that was complemented by a heat lamp.

2.1.2. Audio/video recordings

Each pen was equipped with a directional microphone (model NTG-2, RØDE, Australia) installed above the pens' centre in 2.4 m height and directed downward towards the floor. Acoustic data was analysed for stress articulation between day -1 and day 14 post-partum using one PC per pen, each running the STREMODO software. At the detection of stress for at least 0.75 s, a video sequence was recorded using simple webcams (3030i POE, Edimax, Taiwan) to document the sows' and piglets' behaviour. The webcams were installed next to the pen in 2.4 m height with a viewing direction towards the pens' centre. Each video contained 2 min prior to the detected stress articulation and 2 min after.

2.1.3. Video content labelling

The videos were subsequently analysed whether a trapped piglet could be visually confirmed. Since the development of the monitoring system was still in progress, no valid classification performance regarding erroneously not detected trapping events could be obtained. However, no lethal crushing event was missed by the system. The evaluation of the videos from the development phase yield observations of 3 lethal piglet crushing and 7 events where piglets were trapped under the sow. With an average litter size of 12, about 13 fatal piglet crushing could be expected for 264 piglets according to the literature (Weber et al., 2006).

2.2. Experimental phase

2.2.1. Animals and housing

Altogether, for 20 sows (German Large White × German Landrace) the farrowing and behaviour of 271 piglets was observed until their 14th day post-partum using audio and video recordings. The sows were housed individually in farrowing crates in groups of 4 on slatted floor in an experimental farrowing compartment within a commercial pig production and fattening facility. No nest building material was provided. The sows ranged between 1st and 7th parity. The piglets were provided with a floor heated creep area that was complemented by a heat lamp.