Using sound location to monitor farrowing in sows

E. van Erp-van der Kooij[1,*], L. F. de Graaf[1], D. A. de Kruiff[1], D. Pellegrom, R. de Rooij, N. I. T. Welters and J. van Poppel[1]

[1]*Department of Animal Husbandry, HAS Green Academy, University of Applied Sciences, PO Box 90108, 5200 MA, 's-Hertogenbosch, the Netherlands*

[*]Corresponding author: Lenny van Erp-van der Kooij, l.verp@has.nl

Abstract

Welfare of sows and piglets receives increasing attention. PLF systems to aid farmers in monitoring pig health and welfare slowly reach the market. Automated behavior monitoring via sound and vision could help farmers to prevent health and welfare issues around farrowing. Five sows were monitored in two field studies. A Sorama L642V sound camera, providing sound source localization through a 64 microphones array, visualizing sound sources as colored spots, and a Bascom XD10-4 security camera with built-in microphone, were used to record vision and sound of sows, piglets and environment around farrowing. In field study 1, sound spots were compared with audible sounds, using The Observer XT (Noldus Information Technology), analyzing video data at normal speed. This gave many false positives, with visible sound spots but no audible sounds. Accuracy was 19.7%, error percentage 80.3, sensitivity 45.3% and specificity 12.8%. During farrowing, 16 from 50 piglet births were visible, but none audible. One piglet was crushed, without any sound. In field study 2, data were analyzed at a 10-fold slower speed and sound spots were compared with audible sounds and sow behaviour. This resulted for audible sounds in 43.6% accuracy, 56.4% error, 100% sensitivity and 9.6% specificity and for sow behavior in 38.8% accuracy, 61.2% error, 100% sensitivity and 8.9% specificity. We conclude that sound cameras are promising tools, detecting sound more accurately than the human ear. There is potential to use sound cameras to detect onset of farrowing, but more research is needed to detect piglet births or crushing.

Keywords: sows, piglets, sound analysis, farrowing, behaviour

Introduction

It is estimated that by 2050, the human world population will be more than 9 billion, consuming 50-60% more food than at present. The expectation is that the majority of people will still prefer animal protein over plant-based food and the demand for livestock products will grow. At the same time, food insecurity will increase globally (Benjamin and Yik, 2019). Sustainable intensification is one of the solutions, considering the need for increased food production, food coming from existing agricultural land, and a wide range of production methods and tools (Charles et al., 2014). With intensification of food production and industrializing of animal production systems comes the fear of decreased animal welfare (Broom, 2010). People in general feel a duty of care towards animals, whether they are the animals that they keep, encounter or eat (Broom, 2010). While meat production will increase, the expectation of society is that animals used for meat are treated humanely and individually. Precision Livestock Farming (PLF) can improve or monitor animal welfare on farms, if properly implemented (Banhazi et al., 2012). PLF can be defined as managing livestock production using the principles of process engineering. Smart sensors are used to measure and monitor animal health and welfare (Wathes et al., 2008). Several sensors have been developed for the livestock sector, focusing on different aspects of the production process. For pigs, the main focus is on health and productivity of pigs, with sensors such as cameras, microphones, thermometers and accelerometers being developed and applied (Benjamin and Yik, 2019). Examples of applications in practice are weight estimation with cameras, water meters to monitor water intake and a sound sensor monitoring coughing. A new development is the application of a sound camera, providing sound source localization through an array of 64 microphones and visualizing sound sources as colored spots. This type of camera has been developed for various purposes such as noise control and monitoring of mechanical systems, in unmanned vehicles or in the rescue of victims in disaster areas (Jung and Ih, 2022). Sound cameras are presently used in crowd control under outdoor conditions (Nguyen et al., 2016) and introduced in ecology (Mennill et al., 2012) and agriculture. Possibly these cameras can be of use in monitoring welfare in pig farms. Intensification of pig farms increases the risk of welfare challenges as a result of low space allowance for the animals, a high degree of confinement, use of stated floors and insufficient climate conditions (Pedersen, 2018). Automated behavior monitoring via sound and vision could help farmers to prevent health and welfare issues. For sow farms, relevant welfare issues around farrowing are a stagnating birthing process possibly resulting in stillborn piglets, and crushing of piglets after farrowing (Singh et al., 2017; Skovbo et al., 2022). Therefore in this study we focus on the farrowing process. We have used a sound camera together with a security camera to monitor sounds, vision and sound location around farrowing, as the first step in developing a sound-based early warning system for a stagnating birthing process and the prevention of piglet crushing.

Materials and methods

Animals and test set-up

The study was performed at a commercial pig farm with two farrowing units for 64 sows each. Sows were monitored around farrowing, staying in a farrowing pen of 2.80*1.75 meter with a farrowing crate of 2.1*1.0 meters. Two Bascom XD10-4 security cameras that showed sound and vision were placed above the pens to record audible sounds and behaviour of sow and piglets, with each camera viewing two pens. Three Sorama L642V sound cameras were placed directly above three farrowing pens, with each camera viewing one pen (Figure 1). The L642V is a camera with an array of 64 microphones showing sound location and intensity as colored sound spots at the location of the sound.

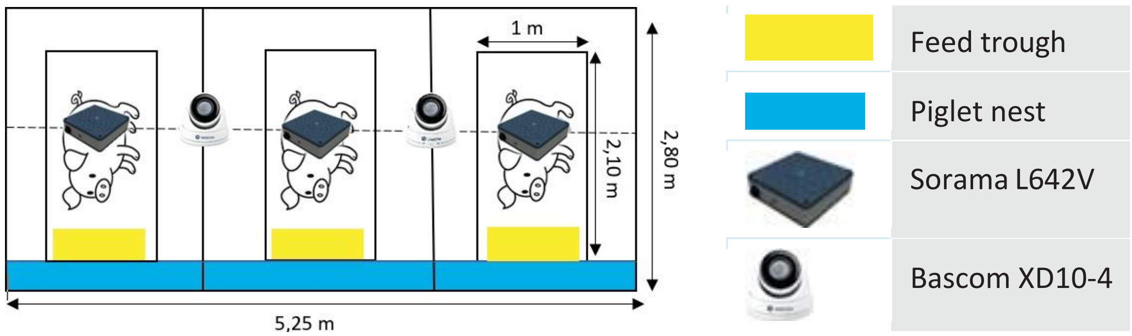

Figure 1: Experimental set-up for three sows with two Bascom XD10-4 security cameras and three L642V sound cameras.

Recording of sound and visual data

Data from the cameras could not directly be recorded, due to the safety settings. We therefore streamed the data to three laptops in the office of the farm. The screen of the laptops showed the image of the security camera and the sound camera side by side, as well as a clock, in order to synchronize the images if necessary (Figure 2). We recorded the data using the Screen recorder software Open Broadcast Software (OBS-studio), resulting in video files in mp3 format. Laptops were remotely controlled using TeamViewer.

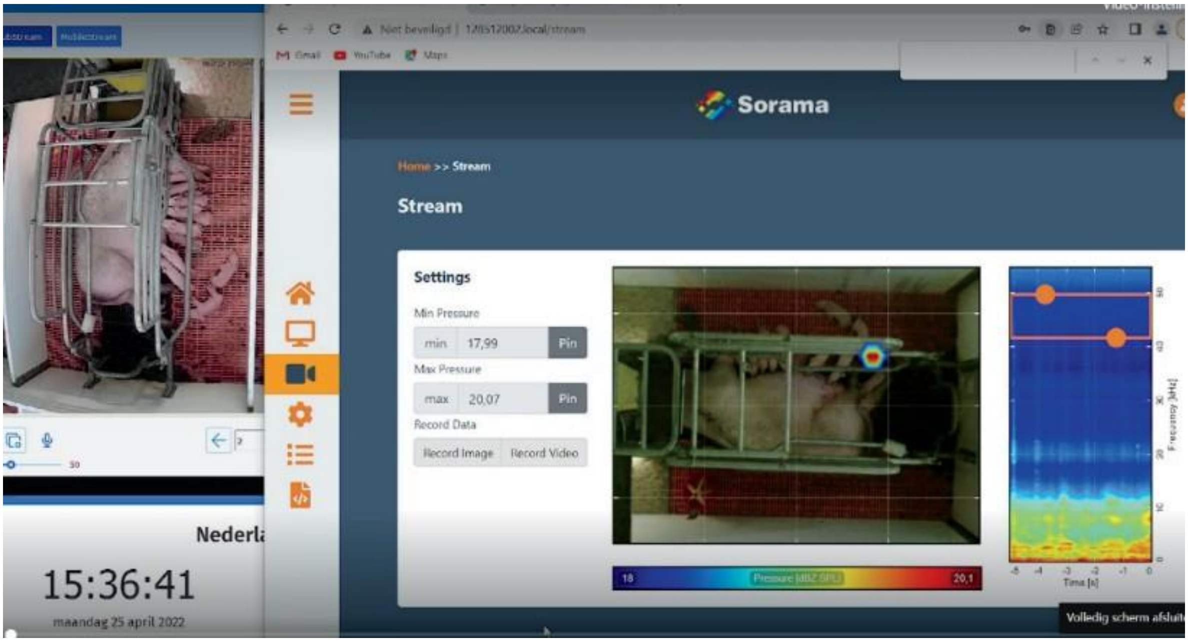

Figure 2: Screen capture used for analysis of behaviour and sound in the farrowing pen.

Analysis of sound and visual data, field study 1

Approximately 45 minutes of video data from each of four sows were analyzed after the first field study. Audible sounds were recorded from the recorded video of the security camera. Visible sounds were recorded from the sound camera. When a sound spot was visible at roughly the right location within a time period of ±1 second from the audible sound, the spot was considered correct positive. Audible sounds with no corresponding sound spot were considered false negative. Sound spots with no audible sounds were considered false positive. Finally, when no sound was visible or audible for a period of 2 seconds, this was considered correct negative. In Table 1, the connected audible and visible sounds and sound locations are shown.

Table 1: Sound spots and corresponding audible sounds that were considered correct, field study 1.

Sound spot	Audible sound
Head of sow	Sow in crate
Rump of sow	Sow in crate
Fence	Metal fence
Head of sow	Trough
Trough	Trough
Outside pen	Neighbor sow
Cloud of sound spots	Neighbor sow

Analysis of sound and visual data, field study 2

Data from three sows were analyzed after the second field study. From the security cameras, sow behaviors and audible sounds were recorded and from the sound camera, sound spots were recorded, for a short period during farrowing. When a sound spot was visible at roughly the right location within a time period of ±1 second from the audible sound, the spot was considered correct positive. Audible sounds with no corresponding sound spot were considered false negative. Sound spots with no audible sounds were considered false positive. Finally, when no sound was visible or audible for a period of 2 seconds, this was considered correct negative. In Table 2, the connected audible and visible sounds and behaviors are shown.

Table 2: Sound spots and corresponding audible sounds and corresponding behaviors that were considered correct, field study 2.

Sound spot	Audible sound	Sound spot	Behavior
Head of sow	Front of pen	Head of sow	Playing with jute sack
Rump of sow	Metal fence	Head of sow	Eating
Fence	Metal fence	Trough	Eating
Head of sow	Trough	Rump of sow	Standing
Trough	Trough	Fence	Standing
Outside pen	neighbor sow	Fence	Moving leg lying
Cloud of spots	neighbor sow	Outside pen	-
		Cloud of sound spots	-
		-	Lying down

Results and discussion

Data from five sows in two field studies were gathered and analyzed for visible sounds (sound spots), audible sounds and in field test 2 also for visible sow behaviour. There was a minor time lag in the recording of the visible sounds of approximately 1.5 seconds, which was corrected for by adding 1.5 seconds to the recorded times of the sound spots.

In the first field study, we compared audible and visible sounds of the sows before farrowing and recorded 13,351 sound spots and 981 audible sounds in 177 minutes of video data. We found a low agreement between the sound and vision data (Table 3).

Table 3: Results of visible and audible sounds before farrowing in the first field study (N=4 sows, 177 minutes).

	Wrong location considered false negative	Wrong location considered correct positive
FP	10,751	10,751
FN	1,823	76
CP	1,509	3,256
CN	1,582	1,582
Accuracy	19,7	30,9
Error %	80,3	69,1
Sensitivity	45,3	97,7
Specificity	12,8	12,8

In this study, the human observer was the gold standard for audible sound. In comparing manual to automated scoring, there are some problems with finding the gold standard or ground truth. Clinical research has taught us that manual scores are usually qualitative or semiquantitative, and subjective, even when done by a seasoned observer, while automated image analysis is quantitative, reproducible and objective. The visual and cognitive traps of manual image analysis are listed by Aeffner et al. (2017) and can easily be extrapolated to manual sound analysis. The traps, or sources of bias, include illusion of size (size being influenced by the context in which it is displayed), distinguishing colors, and lateral inhibition (increased response to edges). For sound analysis these would translate to illusion of loudness (being influenced by loudness of other sounds), distinguishing pitch (depending on pitch of surrounding sounds) and increased response to short and sharply defined sounds. General sources of bias are inattentional blindness (i.e. not paying attention) and confirmation bias (i.e. hearing what you expect or want to hear). Labelling audible sounds from video, recorded with a safety camera, probably resulted in many false negatives for audible sounds and inaccuracies in the labelling, since the human observer either hears the sound and reacts too late, or not hears the sound at all, while the sound camera does receive the sound. Furthermore, the labelling of the sound spots was probably not accurate enough, since we labelled at normal speed. This resulted in many 'cloud of sound spots' events, with a cluster of sound spots occurring at once. Playing the videos at a 10-fold slower speed showed that the sound spot clouds were actually a series of sound spots that started with one or two spots in the correct place, followed by a cluster of spots in the area. For example, a sound spot cloud near the head of the sow was in reality the sow moving her head, bumping into the fence; analyzing this event at a slower speed showed a sound spot near her head, followed by one near the fence, and subsequently many sound spots running along the fence. This made us adjust the analysis for the second field study. During farrowing, birthing events were selected and after farrowing, crushed piglet events were selected in the first field study. 16 from 50 piglet births were visible on the sound camera, and gave sound spots in the correct area, but no birth events were audible.

In the second field study, we analyzed 3 minutes (180 seconds) of video from one sow during farrowing. Video data was analyzed at a 10-fold slower speed and audible sounds, sow behaviour and sound spots were recorded. This resulted in a somewhat higher but still unsatisfactory agreement between the sound and vision data (Table 4). Accuracy was a little higher than in the first field test, but still rather low. The fact that the sow farrowed at night, with low visibility on the cameras, probably increased the number of false positives (i.e. sounds visible in a different spot than audible) due to human error. In all tests, we counted way more sound spots than we recorded visible behaviors or audible sounds. This may very well be due to human error. A reliability analysis for labelling sound spots between the observers showed an agreement of 82% but a Kappa value of 0.17 (slight agreement). The high number of sound spots and almost no silent periods leads to a high agreement by chance of 0.78. This lowers the Kappa value (Banerjee and Fielding, 1997; Byrt et al., 1993). Besides, manual labeling of data as the gold standard is a point of discussion.

Table 4: Results of audible sounds, visual sound spots and sow behaviour during farrowing in the second field study (N=1 sow, 180 seconds).

	Audible sound versus visual sound spots	Visible sow behaviour versus visual sound spots
FP	141	153
FN	0	0
CP	94	82
CN	15	15
Accuracy	43.6	38.8
Error %	56.4	61.2
Sensitivity	100	100
Specificity	9.6	8.9

In order to detect the sound of a piglet being born, we selected a period of 3 minutes during farrowing in which this happened. However, this birthing event happened without a visible sound spot and without audible sound. It seems that piglets are born silently.

Conclusions

Sound cameras are potentially interesting to apply in pig farming, since they can detect sounds and sound location better than the human observer. Sound cameras might detect the onset of farrowing by recording sounds from the prepartum sow as she is preparing for the farrowing process. We could not reliably detect piglet births and crushing events in this study. In analyzing sound and visual data it is important that a slower speed is used to record the order of events and sound spots, and that sound data is connected to behaviors that are inaudible for the human ear.

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