ONLINE RECOGNITION AND LOCALISATION OF SICK PIG COUGH SOUNDS

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ABSTRACT

This research focuses on animal welfare and serves as an application to precision livestock farming. A sick cough recognition algorithm is combined with a localisation procedure to identify and localise sick animals (pigs in this work) in their housing environment. It is intended to provide continuous 24 hour health monitoring in pig houses and produce early warning in cases where treatment is needed. Early warning can provide the expert with valuable time to assess the importance of the alert and provide treatment only for the animals that pose a high risk.

Keywords: online sick cough recognition; online health monitoring; animal welfare

INTRODUCTION

Monitoring animal health in pig houses is vital for the sustainable management of a pig farm. Cough is a sudden air explosion in the airways followed by a characteristic sound (Korpáš *et al.*, 1996). Being one of the body's defence mechanisms against respiratory infections, it can be a sign of disorder or infection of the respiratory system. It has been identified as an index for over 100 diseases and experienced physicians can identify an infection based on the cough sound.

The importance of coughing as a means of prognosis does not refer only to humans, but also to animals. It has been shown that pig vocalisation is directly related to pain and classification of such sounds has been attempted (Marx *et al.*, 2003). It is also common practice by veterinarians to assess cough sounds in pig houses for diagnostic purposes. However, this approach cannot be used for continuous monitoring and early warning for infections in pig houses. In this regard, there have been attempts to identify the characteristics of coughing in animals (Moreaux *et al.*, 1999, Van Hirtum and Berckmans, 2001) and automatically identify cough sounds from field recordings (Van Hirtum and Berckmans, 2003, 2003a).

As the use of antibiotics has reached a level that cannot be accepted to guarantee the success of the drug in the future due to the increase of resistance in species, it is strongly recommended to decrease the use of it over all fields of applications. In this regard, apart from recognizing a sick animal sound, it is equally important to localise the sick animal in the compartment and immediately treat only animals in the pen of the animal that has been identified as sick.

In this paper, the aim is to investigate if the time domain characteristics of sound signals can be used to automatically classify sick coughs. Although the connection between the time domain characteristics of the sound and their biological meaning is not fully known, it is shown that they pose an attractive classifier for the case of sick pig coughs. For the localisation of the cough sounds, an algorithm based on the "Time Difference of Arrival" (TDOA) of the signal in 7 microphones is proposed. It is shown that this computationally efficient method provides acceptable accuracy levels for the specific application.

MATERIAL AND METHODS

Experimental data

Three data sets are used in this work. The first one is used to present the classification properties of the time domain characteristics, the second one for the evaluation of the localisation algorithm and the third one for the application of the procedure to field data for both cough recognition and localisation.

The first data set consists of recorded sounds in laboratory conditions. Coughs from healthy animals were induced in an inhalation chamber by injecting an irritating substance, namely 0.8 moles per litre of citric acid dissolved in a saline solution (0.9% NaCl) (for more information on the installation environment and the data acquisition process see (Van Hirtum and Berckmans, 2003a). The nebulisation of citric acid stimulates the cough receptors directly resulting in coughing. In total, 11 experiments were conducted to 3 male and 3 female healthy Belgian Landrace piglets of 9–12 weeks of age and 20–40 kg of weight. The experiments were conducted with individual animals. In order to record pathologic coughs, the piglets were anaesthetised with azaperone (4 mg/kg intra-muscular (IM)), ketamin (10 mg/kg IM) and thiopental (10 mg/kg into a vein). They were treated (by intra-tracheal administration) with lipopolysaccharide from *Escherichia coli* diluted in sterile saline (100 µg/kg). A non-toxic strain of *Pasteurella multocida* (code 3301) was used to generate bronchopneumonia, a common respiratory infection in piglets (Kobish and Friis, 1996). Apart from the cough sounds, other sounds (such as screams, sneezes or metal sounds) were acquired and labelled accordingly by auditory processing (Van Hirtum and Berckmans, 2003a). Therefore, the generated data set includes individual sounds of 231 healthy coughs, 291 sick coughs, 18 screams, 19 sneezes, 31 grunts and 81 metal sounds (e.g. clanging doors).

The second and third data sets consist of field recordings in a fattening compartment of a pig stable in Milan, Italy. The dimensions of the stable were 14 m by 21 m with a height of 3.75 m against the walls and the roof had an inclination of 30%. The floor was totally slatted and the total area was divided into 16 boxes, eight on each side of a central path along the length of the stable. There were 350 animals in the stable, with an average of 22 pigs a box. The pigs were aged three months and were fattened from 26–35 kg at the beginning of a cycle to reach 90–100 kg in 90 days. The genetic line was a cross between landrace Italian X large white X duroc and serve for the Parma ham production. The acquisition was conducted in May 2005.

The second data set consists of triangle sounds recorded by 7 microphones in an empty stable and were produced at a height of 1 m above the ground at predefined positions. These were used to evaluate the accuracy of the localisation algorithm. The third data set consists of continuous recordings by 7 microphones (of 2 hours and 20 minutes duration each) in the pig house during normal operation and was used to test both the recognition and localisation algorithms on field data. The sick animals in this case were suffering from pleuropneumonia from *Actinobacillus Pleuropneumoniae*.

For the sound registration 7 electret microphones (Monacor ECM 3005) were used that have a frequency response of 50–16000 Hz and were connected via preamplifiers (Monacor SPR-6) to an eight channel analogue to TDIF interface unit (Soundscape SS8IO-3). The Soundscape unit, which allows for simultaneous recording of 8 channels, was connected via a TDIF cable to a PCI audio card (Mixtreme 192). All recordings were sampled at a sample rate of 44.1 kHz with a resolution of 16 bit. All microphones were hanging in the stable at a height of 1,20 m at the positions depicted as big dots in Figure 2.

Classification and localisation

The time domain characteristics of the sound signals are used to form a cluster where the sick cough sounds belong. To present the classification properties of the proposed technique, 5 randomly selected sick cough sounds from the first data set are used to form the *sick cough* cluster. The classification procedure is subsequently applied to the whole first data set resulting in 92% correct classification ratio (with 2.8% false positive identification ratio), while 88% of all the sick cough sounds are identified (i.e. 12% false negatives).

The localisation algorithm is based on the “Time Difference of Arrival” (i.e. the difference in time for a sound to arrive at different microphones) of the sound to the microphones that are placed in predefined positions in the pig house. The proposed technique is applied to the second data set in which the triangle sounds were produced in known positions. The algorithm detected the origin of the sounds with an average accuracy of ±61cm and ±34cm along the long and short dimensions of the pig stable respectively. This level of accuracy is considered acceptable for the present application since it is important to identify the pen in which the sick animal is located and not necessarily the sick animal itself.

Analysis of field data

The flow chart for the proposed application for cough recognition and localisation is shown in Figure 1. It comprises mainly of three sub processes, namely the sound extraction, the cough recognition and the localisation, that are presented in the following.

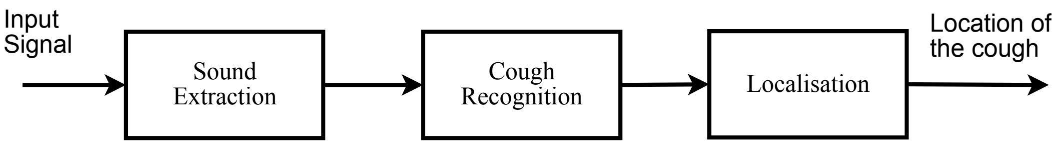

Figure 1. Flow chart for the procedure of sick cough recognition and localisation

Table 1. Results of the cough recognition algorithm on the field data

Microphone	Total Number of Sounds indicated by the algorithm to be sick coughs	Number of sounds that were correctly identified as sick cough	Percentage of correct identification
1	88	64	73%
2	101	76	75%
3	41	33	80%
4	40	37	93%
5	35	29	83%
6	47	38	81%
7	37	31	84%

To reduce the computational load for the online application, and since the pig vocalizations do not include frequencies higher than 10 kHz (Van Hirtum and Berckmans, 2001) the data are downsampled to 22.05 kHz. Furthermore, to deal with low frequency noise, and since the sick cough signals that need to be recognized do not have considerable low frequency components (Van Hirtum and Berckmans, 2001, 2003), the signal is initially bandpass filtered. For this, a 10th order Butterworth filter with pass band 2–10 kHz is used.

RESULTS AND DISCUSSION

The cough recognition and positioning procedures described above are applied to the continuous recordings of the third data set. The first five cough sounds from each microphone were manually extracted from the continuous recording, labelled by auditory means and used as a training set to define the cough clusters for every microphone. It is necessary to construct a different cluster for every microphone since the acoustics of the compartment have a different effect on each microphone mainly due to the location of the microphones (four are located in the corners, two against just one wall and one in the middle of the compartment). The result is presented in Table 1.

On the correctly recognized cough sounds, the positioning algorithm is applied and the result is presented in Figure 2. It can be seen that a clear *cough hazard* can be located at the bottom left corner and another one might be occurring at the middle left side of the pig house. Although coughs are detected in other places of the pig house, it is clear that not all of them can be considered as a hazard and an alarm should occur only for the two mentioned areas. Since a sick cough would be repeated, coughs detected in areas others than the ones mentioned, could be the result of algorithm failure or isolated cough events that pose no threat to animal welfare in the pig farm.

To the authors' knowledge, this is the first application for combined cough recognition and positioning presented in the relevant literature and can pose as a starting point for further research. The results seem promising, although there are still issues to be considered. At this point, if a cough is identified in the recording of a single microphone, the recognition is considered correct and the cough is located. A possible enhancement could be based on a trade off between sensitivity and correct recognition perhaps requiring a sound to be identified as a cough from more than one microphone.

The classification based on the time domain characteristics of the sounds is a simple technique and the computational load is held to a minimum. It is clear that a connection between them and the cough production procedure needs to be made to theoretically justify the results presented here. It is clear that superior techniques for pig cough recognition from continuous recordings exist (Van Hirtum and Berckmans, 2003a). However the repetition of sick coughs in a pig house allow for the application of the proposed technique. It is computationally effective and provides the necessary accuracy of the specific application. Another issue that still remains to be studied is the effect of environmental noise to the time domain characteristics of the sound and how this affects the accuracy of the proposed technique. It is known however that training of the algorithm needs to take place before applying it to a new environment, but the accepted level of the surrounding noise still needs to be determined.

Since the application of pig cough localisation is in pig houses, the accuracy of the algorithm to be used need not be very high, considering animal movement and that the objective is to identify the area that needs to be treated. Hence a simple sound initiation detection technique for determining the TDOA is applicable.

CONCLUSION

An automatic algorithm for sick cough recognition and localisation has been presented. Both the recognition and the localisation processes are based on simple and computationally effective algorithms, making it an attractive solution for fast observation of the spread of a disease in a pig house.

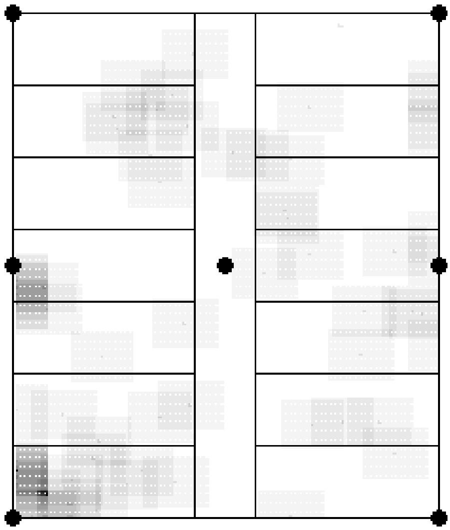

Figure 2. Representation of the pig housing environment where the dark areas indicate the positions of sick animals as a result of the proposed algorithm. Two possible health hazards emerge (at the bottom left corner and at the middle of the left wall)

The sick cough identification algorithm is based on analysis of the time domain characteristics of the sound signal and has been shown to be a potential classifier for sick pig cough sounds. Although the nature of the connection between the time domain characteristics and the physical system parameters for pig vocalizations is not yet known, the present results indicate that such a connection does exist and will be the subject of further research.

It is suggested that the present application can be used to continuously monitor animal health and that it can help in the improvement of animal welfare in pig houses. This can lead to early identification of sickness in a pig compartment and selective treatment of sick animals in the pens of the identified hazard.

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REFERENCES

1. Korpáš, J., J. Sadloňová, and M. Vrabec. Analysis of the cough sound: An overview. *Pulmonary Pharmacology* **9**, 261–268 (1996).
2. Marx, G., T. Horn, J. Thielebein, B. Knubel, and E. von Borell. Analysis of pain-related vocalisation in young pigs. *Journal of Sound and Vibration* **266**, 687–698 (2003).
3. Moreaux, B., D. Beerens, and P. Gustin. Development of a cough induction test in pigs: effects of SR 48968 and enalapril. *Journal of Veterinary Pharmacology and Therapeutics* **22**, 387–389 (1999).
4. Van Hirtum, A., and D. Berckmans. The fundamental frequency of cough by autocorrelation analysis. In *Proc. EUROSPEECH: 7th European Conference on Speech Communication and Technology*, 2435–2438, Aalborg, Denmark (2001).
5. Van Hirtum, A., and D. Berckmans. Considering the influence of artificial environmental noise to study cough time-frequency features. *Journal of Sound and Vibration* **266**, 667–675 (2003).
6. Van Hirtum, A., and D. Berckmans. Fuzzy approach for improved recognition of citric acid induced piglet coughing from continuous registration. *Journal of Sound and Vibration* **266**, 677–686 (2003a).
7. Kobisch, M., and N. Friis. Swine mycoplasmoses. *Revue Scientifique et Technique De L'Office International des Epizooties* **15**, 1569–1605 (1996).