LABELING OF COUGH DATA FROM PIGS FOR ON-LINE DISEASE MONITORING BY SOUND ANALYSIS

J.-M. Aerts[1], P. Jans[1], D. Halloy[2], P. Gustin[2], D. Berckmans[1]

[1]Laboratory of Agricultural Building Research, Department of Agro-Engineering and Economics, Katholieke Universiteit Leuven, Belgium;

[2]*Department of Pharmacology, Pharmacotherapy and Toxicology, Universite de Liege, Belgium.*

Abstract. **More objective and automated detection of respiratory diseases in pig houses should be possible by on-line sound analysis of cough monitoring. To develop automatic algorithms for pig cough recognition, experiments and well-labeled cough data are needed. The objectives of this article are: (1) to give a short overview of the attained results in cough recognition, and (2) to define a methodology to label the cough data in a pig house. Human observers labeled coughs by audiovisual observation in a laboratory test installation with ten pigs during periods ranging from two days to two weeks. Simultaneously, sound registration was done with audio equipment. The sound registrations were listened to by another observer to compare the number of coughs in the registration with the number labeled during the experiment. It was found that there were underestimations of up to 94% in the number of coughs. The underestimation in the number of coughs could be reduced to 10% when the observer used an additional labeling sound signal on the scene each time coughing was observed. In addition, differences were found between two independent observers scoring pig's coughs in an audiovisual manner on the scene. For future research, we suggest an investigation of how an observer using software labeling could improve the labeling results.**

I. INTRODUCTION

is not only crucial for the animals' health and welfare [6,7], but also for the consumer because early detection of animal diseases can reduce residuals of antibiotics in meat products [8]. Therefore, great effort is spent to the development and application of sensors and sensing techniques for diagnosis in livestock farming [9]. Sound production by animals is a candidate bio-signal that can be measured easily at a distance and without causing additional stress. Research has been reported on sound analysis applied to animal sounds in general [10,11,12,13,14,15] and to farm animals in particular [16,17,18,19]. Sounds produced by pigs have been analyzed in relation with communication [20,21,22,23] stress [24,25], welfare [10,17], pain [26,27], and health [19]. Because respiratory diseases cause important economic losses in pig production [19], several researchers in recent years have focused on cough detection algorithms. Examples can be found in the work of [28,18,13]. A common characteristic of the developed algorithms is that they are trained based on data sets (training data sets) in order to classify the measured sounds (e.g., with neural networks). As a consequence, the failure or success of the development of an algorithm depends highly on the quality of the training data set. In order to quantify the success rate of such algorithms, the data sets (training as well as validation) are labeled. This means that the recorded files are listened to by a human and every sound is marked and described. However, the person who labels the sound files in the laboratory is not necessarily the same person who attends the experiments on the scene (observer). In some cases, e.g., measurements at night, an observer is not even present during the experiments. Because listening to sounds in general and cough sound files in particular is prone to subjectivity and human error, questions have arisen about the accuracy of the classical labeling procedure. In the reported research, the objective was to analyze the accuracy of the labeling of cough sounds in pig and to improve the labeling procedure for cough sounds.

II. METHODOLOGY

Animals and Housing

Throughout the experiments, the same group of ten piglets (Belgian Landrace) was used. They weighed about 9 kg at the start of the experiment. The pigs were housed in a 2 × 5 m pen with a partially slotted floor that was situated in the test facilities of the Faculty of Veterinary Medicine, Université de Liège (Belgium). Room air temperature was 20°C ±2°C. The ventilation rate was 8 m^3 h^{-1} per pig. A light scheme of 16 h of light and 8 h of darkness was applied. Light intensity was 60 lx during the light period. During the experiments, the piglets were fed a commercial feed, and water was freely available.

Digital Sound Recording

The sounds were recorded by using a standard multimedia microphone (U.S. Blaster, 20 Hz to 20 kHz frequency response), connected to a sound card (Sound

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Blaster, 16 bit). The microphone was positioned 0.3 m above the pen. The sound files were recorded as .wav files (plain sound file) with a frequency of 22.050 Hz. In the laboratory, the sound files were listened to by Cool Edit Pro (version 1.2a).

Experiments

In total, four experiments were carried out. During the first three experiments (Exp1, Exp2, and Exp3), the pigs' coughs were scored during one hour a day (0830 h to 0930 h) in the test installation by an observer. The experiments lasted 22, 19, and 17 days for Exp1, Exp2, and Exp3, respectively (see table 1). During the recording time, an observer was present in the test facility in order to score (count) the coughs. The recorded sound files were then scored by a second person in the laboratory by looking at the shape of the signal (in the time domain) on a computer screen and by listening to the sound file by headphone at the same time (i.e., audiovisual scoring).

In the fourth experiment (Exp4), the listening time was extended to five 1 h periods a day (0830 h to 0930 h, 1330 h to 1430 h, 1830 h to 1930 h, 2330 h to 0030 h, and 0430 h to 0530 h), during five non-consecutive days (see table 1). Each time a cough was observed, the observer produced a typical sound, called a "ping," to label the sound as a cough. The "ping" was made by hitting a glass bottle with a metal stick. The hypothesis was that this typical sound could be easily recognized by the person scoring the sounds afterwards in the laboratory.

The first day of Exp4 was carried out with two observers in the test installation. They could both see and hear the piglets, but they could not see each other. For this part of the experiment, no labeling sound ("ping") was used.

Statistics Used

Statistical significance between mean values of coughs counted was tested using a two-sample t-test. Since the observations on the two populations of interest were collected in pairs, a paired t-test was used [29]. In order to test the hypothesis on the equality of the mean numbers of coughs counted on the scene and in the laboratory (see table 1), the data from Exp1, Exp2, and Exp3 were used. The data from Exp4 were not used for this analysis since the observations were made in a different way (labeling sound). For testing the hypothesis on the equality of the mean numbers of coughs counted by observer 1 and observer 2 during the first 24 h of Exp4 (see table 2), the data of the five observation periods were used.

III. Results and Discussion

Table 1 gives an overview of the counted coughs in the four experiments. In this research, we used a total of 83 h of audiovisual observations of the pigs' coughs.

Table 1. Scoring of the cough sounds by observer present in the test installation compared with audiovisual scoring afterwards in the laboratory on the recorded audio file.

Experiment	Listening Protocol	Duration (days)	Number of Coughs Counted by Audiovisual Scoring: On the Scene	In the Lab	Under-Estimation (%)
Exp1	1 h/day	22	47	18	62
Exp2	1 h/day	19	97	6	94
Exp3	1 h/day	17	43	17	61
Exp4	5 h/day[a]	5	265	239	10

[a] During Exp4, a labeling sound ("ping") was used.

From table 1, we see clearly that it is not possible to make a well-labeled reference data set just by audiovisual scoring of the recorded files in the laboratory because underestimations of up to 94% occur. It could be demonstrated that the average number of coughs counted by audiovisual scoring in the laboratory was significantly different from the number of coughs counted by the observer in the test installation ($P < 0.2$). This implies that reliable labeling demands at least one observer in the pig house, which is a time-consuming and mentally exhausting job. When the coughs are marked by a well-recognizable sound ("ping") in the audio file (Exp4), an underestimation of about 10% between the different scoring methods was observed. This deviation could be the result of an over- (or under-) estimation of the number of coughs in a series (bout). When, in practice, a bout of coughing occurs, the observer could only make his labeling sound at the end of the series.

Another possible problem, which cannot be put easily into figures, is the conditioning aspect of the labeling sound. Since the pigs could hear the labeling sound themselves, it is possible that, by hearing the labeling sound each time they cough, the pigs get used to it and after a while begin to cough voluntary to hear the labeling sound. Studies with humans have shown that voluntary cough sounds have different features from "normal" cough sounds [14]. Indications for this conditioning effect might be found in the fact that the average counted number of coughs per hour of observation in Exp4 (with labeling sound) was on average 10, whereas the average counted number of coughs (on the scene) per hour for Exp1, Exp2, and Exp3 (without labeling sound) ranged between 2 and 5. However, for a more in-depth analysis of the possible conditioning effects of labeling sounds, more experiments should be performed. Although the use of a typical labeling sound reduced the underestimation to 10%, this is not the way a reliable reference data set of cough sounds can be achieved.

When looking at table 2, we see that there is a difference (but not statistically significant) between the two observers counting the coughs of the same animals at the same time. This gives rise to the thought that there is no real completely objective way to label pigs' cough sounds in practice. We could approach a more objective labeling by mixed subjective observations, but then we would need a number of observers in the pig house, which leads to other problems (e.g., increased costs).

Table 2. Number of cough sounds counted of the same animals at the same time by two different observers in the pig house during the first 24 h of Exp4.

No. of Observations	Time of the Observation	Number of Coughs Counted by:	
		Observer 1	Observer 2
1	0830 h - 0930 h	8	10
2	1330 h - 1430 h	13	12
3	1830 h - 1930 h	7	8
4	2330 h - 0030 h	0	0
5	0430 h - 0530 h	12	7

An alternative to the auditory labeling of cough sounds is software labeling. While recording the sounds in a pig house on a portable computer, we can run an extra program. Whenever a cough sound is heard, a key on the portable computer is pressed, and the program keeps record of the relative time in the recorded audio file. This way, we could get around the problem that pigs might cough to hear the label sound, and we can label each cough, even when coughs come in a series.

In general, it is not easy to reliably distinguish between different animal vocalizations (classification). In order to solve this problem, several authors used signal analysis techniques in combination with classification procedures to identify individual vocalizations in a more objective way [21,25,27]. They used classification techniques based on training data sets. Most of the time, individual sounds are labeled by ethologists listening to the recorded data in the laboratory (e.g., [16,17]). Due to (mechanical) background noises, it is not always easy to reliably label individual sounds [16]. As described in the reported research, labeling individual cough sounds of pigs can be performed most reliably by at least one observer on the scene in the pig house. However, in most cases described in the literature, labeling was performed on recorded sound data, and no indication is given of the accuracy of the labeling procedure compared with labeling results of observers during the experiment. Accuracy of the labeling procedure is sometimes expressed as the correlation between the scores of two independent persons listening to the recorded sound data. Weary and Fraser [17] used this method for labeling the calls of piglets at weaning and found a correlation between two independent scorers of 0.98. In our experiments, the correlation between the scores of two independent observers in the pig house was 0.85.

All together, we can state that labeling individual sounds in an audio file, to use as a reference set in algorithm training, is a difficult task and must be done very carefully.

IV. CONCLUSION

With the rising interest in animal vocalizations as a valuable biological response variable, there is a growing need for good labeling methods. Cough recognition algorithms cannot satisfy in-field situations when they are not developed, or trained, by a stable, reliable reference set.

Audiovisual observation on a recorded pig sound file is clearly insufficient for accurate labeling of cough sounds. Up to 94% underestimation of the number of cough sounds was scored in an audiovisual way on the computer. Audiovisual observation of the animal on the scene, together with a typical labeling sound, reduced the underestimation to 10%. Since the labeling sound can possibly stimulate the pigs to cough (due to conditioning), this method is probably not suited for generating high-quality data sets (for training and validation). Therefore, we suggest performing additional research to test alternative labeling methods. One of the possible alternatives is to put at least one audiovisual observer in the pig house with a portable computer. While recording the sound file, another program could keep track of the elapsed time. When a cough sound is heard, the observer could press a key on the portable computer. As a result, we could get a sound file and a relative time for all cough sounds during the period of observation, without influencing the animals with labeling sounds.

There were also differences between two independent observers who labeled pigs' cough sounds in an audiovisual way on the scene in the pig house.

V. REFERENCES

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