Assessment of Dairy Cattle Welfare through Acoustic Analysis: Preliminary Results Using a Digital Phonendoscope

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Abstract

The efficiency of dairy cattle production is crucial in a context of population growth. Over the last decades, animal welfare has become a fundamental concern for consumers and for the dairy industry. In addition, evidence shows that improving the welfare of cows increases their production efficiency, the economic return of dairy farms and reduces their environmental impact. Animal welfare assessment normally relies on temporary indicators. Tools available for this purpose are costly, time consuming, discontinued and sometimes invasive. Bioacoustics assessment of the internal organs of cows through a phonendoscope-like device is non-invasive and can continuously inform about the welfare status of an individual cow. This contribution shows the preliminary results of a feasibility analysis on listening to the sounds of internal organs in cows. Several acoustic measurements identified as respiration, cardiac impulses and peristaltic movements were captured by an expert using a digital phonendoscope. In this work, we describe the acoustic characterization of the identified signals, mainly breath and cardiac impulses. The cardiac impulses are present in most of the measurements, respiration is harder to identify and find in the recording campaign conducted, and we could not determine certain peristaltic movements, despite being preliminary identified visually by the expert. These preliminary results are encouraging, artificial intelligence might assist the assessment of the cows welfare using a non-invasive and permanent system.

Introduction

Bioacoustics is the scientific field that detects, measures, and interprets the sounds produced by animals in different contexts [1]. The study of sounds produced by animals has become highly interesting because of the capacity to detect information in an automatic and constant manner, and non-invasively [2, 3, 4, 5]. In cattle production, bioacoustics have been applied to address situations related to illness identification [3, 6], oestrus detection [2, 7, 8], and welfare assessment [9, 5]. However, other acoustic signals that have received little attention in bioacoustics, such as heart beats, breathing, and enteric motility can provide information about the health status and welfare of animals. For instance, heart beats can inform about the cardiac status of animals but can also be used to monitor stress caused by maternal separation or social isolation, which increases the heart rate of the calves [10, 11]. This information can help farmers to anticipate stress response and reduce their undesirable effects such as reduction of feed intake and the concomitant reduced growth. In the same way, respiration rate can notify about respiratory disorders, thermal comfort, and the emotional arousal, which might alter the wellness of the animal [3, 12]. Finally, enteric motility (i.e. rumination) can provide information about the digestive process [13], but also to complement physical activity to improve the sensitivity of oestrus detection [8].

This project aimed to record heart beating, breathing, and enteric activity sounds from a cow to identify and label acoustic signals using spectrotemporal description. The detection, identification, and correct interpretation of these sounds might work as indicators of animal health and welfare indicators.

Recording Campaign

A total of 18 minutes of raw acoustic audio was collected, using a phonendoscope (see Figure 5). Specifically, two models were used: *i)* a Litman phonendoscope which sends the audio sampled at 4,000 Hz to a smartphone through the EKO app, and *ii)* a Ekuore phonendoscope connected to the audio minijack input of a MacBook. The audios recorded with the latter were sampled at 44,100 Hz.

The manual labelling was done *a posteriori*, and the team could show that:

- Nearly all audio pieces contain cardiac impulse audio (see Figure 1), which enable the project to have several high quality samples of audio to use in the future, and

- Only three audio samples presented sounds coming from the trachea of the animals, mainly related to breath (see Figure 2), which show the difficulty associated with gathering this type of sound.

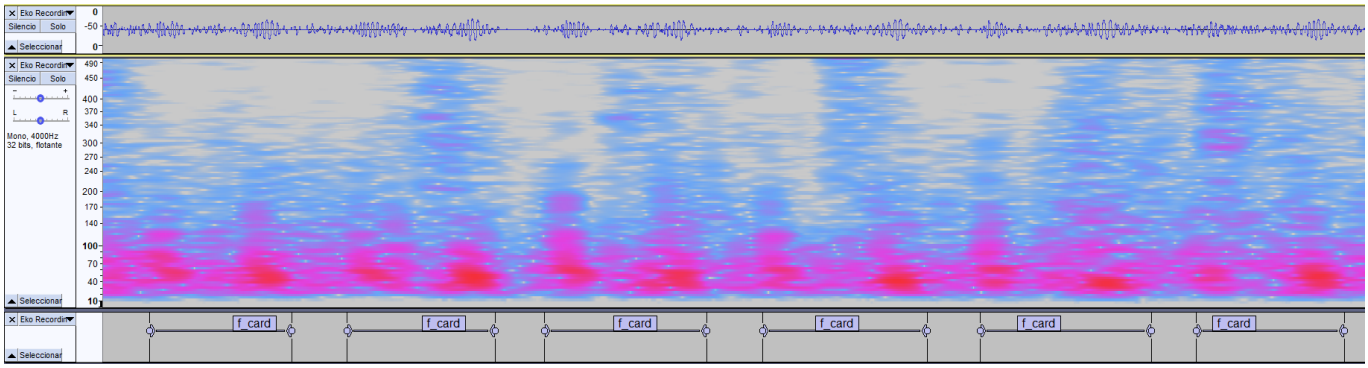

Figure 1: Spectrotemporal detail of several *cardiac impulse* pseudoperiodic sounds recorded by means of a phonendoscope

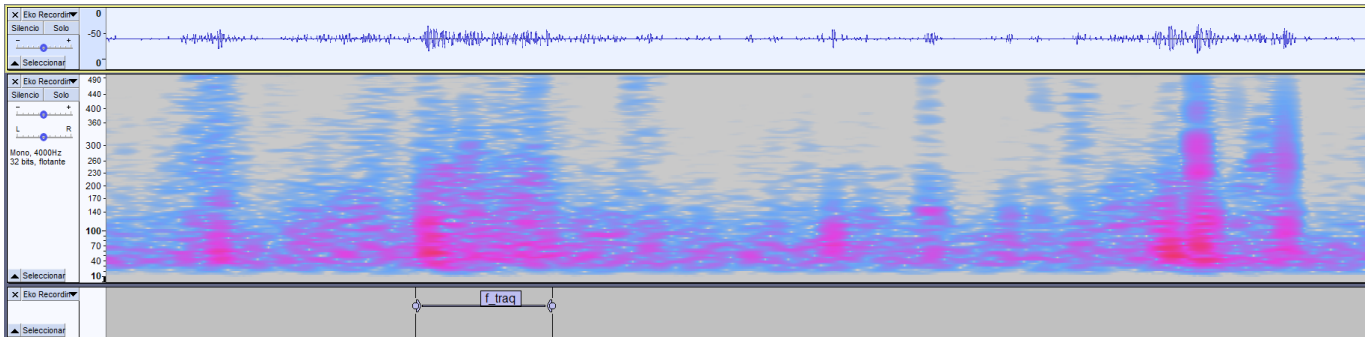

Figure 2: Spectrotemporal detail of a trachea sound, probably due to *breath* of the cow, recorded with a phonendoscope

Table 1: Audio data collected with the two phonendoscopes. Total duration of the recordings and number of cardiac and trachea events found.

Phonendo	Dur (mm:ss)	# cardiac	# trachea
LitmanEKO	03:30	89	1
Ekuore	14:31	343	4

Analysis

The analysis focused on the heart sounds. The individual heartbeats were manually labelled. The distance between heartbeats was computed to obtain the heart rate in beats per minute (bpm).

The audios were cut according to the labels and the obtained clips were merged for analysis. The acoustic analysis was carried out using the python library *pyaudioanalysis* [14], using a window of 50 ms and an overlap of 25 ms. For each window, energy, spectral centroid and spread were extracted.

Results

The first qualitative analysis conducted show us promising results, especially when labelling cardiac impulse sounds recorded by the phonendoscope. As seen in Table 1, 89 and 343 heartbeats have been found in the audio recorded with the LitmanEKO and the Ekuore, respectively. Conversely, trachea sounds were not as common, despite we could only record and label five of such events. Finally, the hardest part corresponded to rumen sounds, which were not found in the 18 minutes of raw audio recorded.

The energy of 500 frames of cardiac sounds recorded with both phonendoscopes is depicted in Figure 3. Energy peaks corresponding to heart beats can be observed. The heart rate computed from the individually annotated heart beats is shown in the left part of Figure 4. The mean heart rate detected is of 58.9 bpm and 53.6 bpm with the LitmanEKO and the Elkuore phonendoscopes. This difference is probably due to the fact that the measures were captured at a different time for each device.

With respect to the spectral characteristics, spectral centroid and spectral spread computed from the cardiac sounds are depicted in Figure 4. Spectral centroid mean is 0.165 and 0.087 for LitmanEKO and Ekuore, respectively. This difference could be attributed not only to the different characteristics of the phonendoscopes but also to the audio captured, which in the LitmanEKO is sampled at 4 kHz while in the Ekuore is digitalized at 44.1 kHz. Spectral spread mean is 0.235 and 0.202 for LitmanEKO and Ekuore, respectively.

Conclusions

The reduced dataset obtained for this work has enabled us to describe the spectrotemporal signal of the cardiac and trachea sound. Due to the technical difficulty of recording the trachea sounds, it was only possible to characterise the cardiac impulse using acoustic descriptors, which included the energy; heart rate; spectral centroid and spectral spread. All descriptors allow and enable to characterise the sound typology. These results, despite not reaching the original objectives, encourage us to label other acoustic data recorded in the field, such as rumen sounds collected by a recorder or environmental sounds

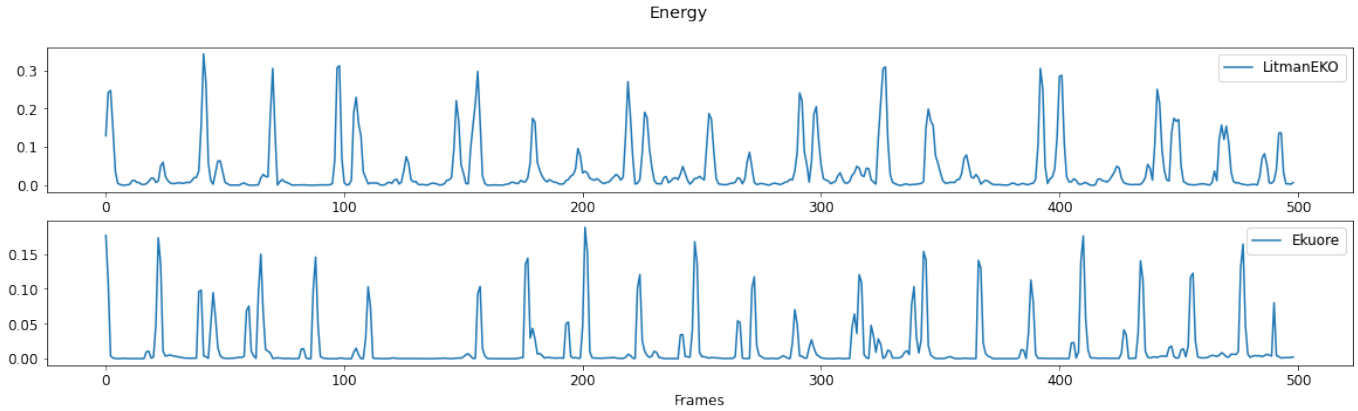

Figure 3: Energy of the heart sound recorded with both phonendoscope: LitmanEKO and Ekuore.

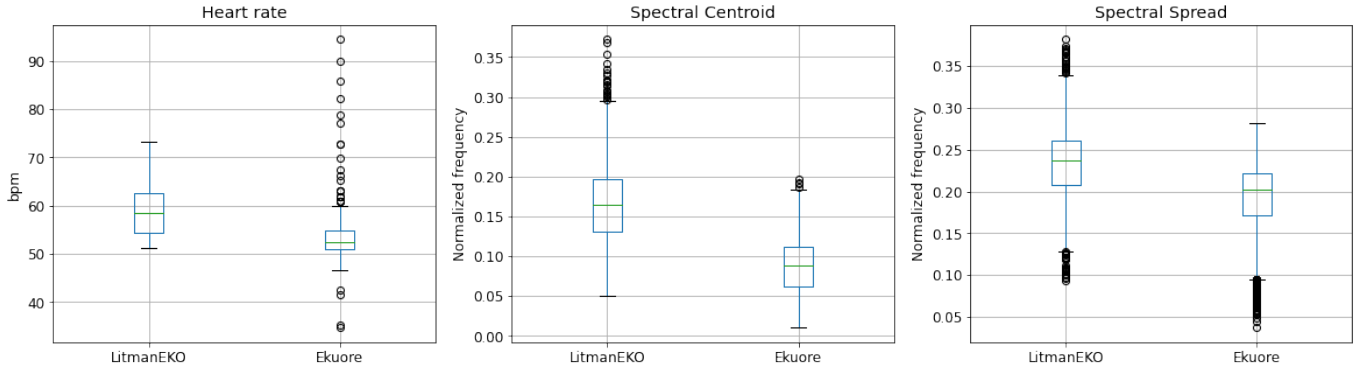

Figure 4: Boxplots of the heart rate, spectral centroid and spectral spread

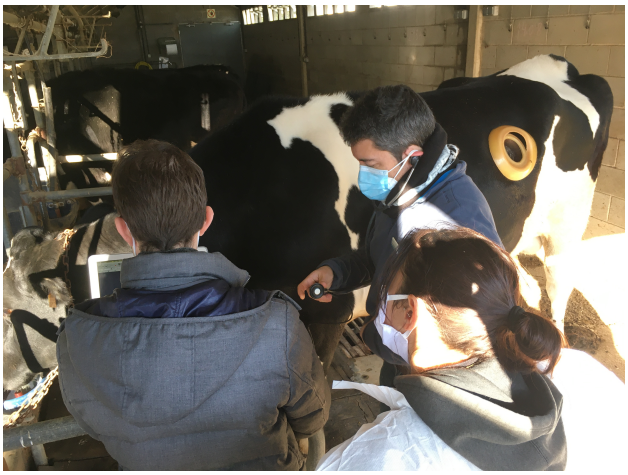

Figure 5: Picture of the veterinarian collecting the phonendoscope samples and recording them with a personal computer.

gathered in a real-world farm environment, in order to find other ways to identify these three targeted sounds. This manual collecting and labelling stage is the previous step to use neural network-based algorithms to automatically identify these sounds in real-time.

Acknowledgements

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