Recording the Heart Beat of Cattle using Optically Pumped Magnetometers

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Abstract

Livestock farming occupies about 30% of the Earth’s habitable surface area with a global value around £3 trillion. This important economic entity relies to a large extent on the health and welfare of the animals involved. Many economic pressure there is also a growing interest from the consumer in the ethical keeping of livestock [Grandin 2014]. The animal’s heart rate is a key indicator of stress and therefore an automated non-contact means of measuring heart beat could enable improved monitoring of animal welfare.

The electric signal of the heart muscle excitation and relaxation does also carries a magnetic field component. Reading the magnetic field to query heart beat information avoids the need for contact electrodes. We use an array of QuSpin Total Field Magnetometers (QTFM). Using the background noise to time-shift the signals we optimize signal to noise ratio and record the magnetic heart signal down to 1 pT Hz-1/2 in the 1–20 Hz frequency band. Using a mathematical algorithm we retrieve the heart rate and the shape of the magnetic heart excitation. Comparison to electrocardiograms shows good correlation.

1. Optically Pumped Magnetometry

Alkali vapour cell magnetometry offers extremely high precision measurements of magnetic fields. Total-field magnetometry allows for the design of compact and robust scalar magnetometers that can resolve small field changes.

2. Magnetocardiography (MCG)

New sensing technologies and data analysis platforms are enabling the development of smart solutions for livestock monitoring, providing farmers and vets with more objective and timely means of monitoring animal health and welfare. Heart beat parameters could offer a potential additional measure of animal condition if they could be captured by non-contact means. Recording electrocardiograms (ECG) on animals comes with challenges in sticking the electrodes to the animal’s skin. Often shaving is required to obtain good contact. Furthermore, in large animals tissue between the electrode and the heart muscle leads to considerable animal to animal variations and to signal distortions [Delloth 1980]. Recording an MCG circumvents these challenges.

3. Sensing Heart Beats

Optically pumped magnetometers have been successfully used in the recording of heart beats and MCGs have been shown to provide rich diagnostic information when using arrays of sensors.

4. Monitoring a Heart Rate

Heart rate is a physiological indicator of animal stress and therefore a potential measure of welfare. It is also an indicator of some diseases, such as milk fever. To be able to track short term variations in the heart rate it is necessary to record the heart rate from short measurement intervals.

Verifying the measured rates against conventional measurements: taking the tail pulse, listening using a stethoscope or taking an ECG, found good correlation between the magnetically recorded and the true heart rate.

5. Recording the Timing of the Heart Beat

The action of the heart muscle is determined by electrical conduction along specialized tissue thus generating a characteristic sequence of heart actions. Magnetic recordings of a cow’s heart beat reproduce the characteristic time intervals as shown in ECG references [Delloth 1980].

6. Matching a MCG with an ECG:

The current standard in monitoring the heart beat is the electro cardiomogram (ECG). We are recording an ECG in the Euroven configuration and match the signal to the magneto cardiomogram (MCG). Aligning the signals from three different ECG configurations with the MCG signal shows matching features in the P-wave, the QRS complex and the T-wave. The amplitudes of the ECGs and the MCG agree with theoretical calculations [Alday et al. 2016].

Conclusions & Outlook

Non-contact sensing of physiological parameters opens opportunities for the monitoring of animal wellbeing in farming and provides an early-waring system for the health of the animal. While a potential strength of an ECG lies in its versatility in picking up different electrical aspects of the heart action it is also prone to interference from other tissue leading to considerable animal to animal variation [Delloth 1980]. A MCG offers potentially better reproducibility and standardisation of measurements.

References:


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