Accurate monitoring of the rumination behaviour of cattle using IMU signals from a mobile device

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Abstract

Improving the monitoring of rumination in cattle could help in assessing of the welfare status and their risk of acidosis. In this work, the monitoring of cattle's behaviour was performed using the inertial measurement unit (IMU) present in smartphones mounted on the neck of cows. The processing of both time and frequency domains of the IMU signals was capable to detect accurately the main behaviours (grazing, rumination and other) and highlight the characteristics of the rumination process. The algorithm for analysis of rumination was more accurate for grazing cattle than for silage-fed cattle in stables.
Keywords: Cattle, behaviour, rumination, signal processing, IMU

Introduction

All animal species display behaviours that indicate their physical, physiological, and welfare status (Frost et al., 1997). For ruminants, grazing, ruminating and resting behaviours occupy more than 90% of the time budget of the animal on pasture (Kilgour, 2012).
Rumination represents 5 to 9h/d for cattle (Vallentine, 2001). It is a cyclic process which completes the chewing of fibrous ingested feed after it underwent anaerobic fermentation by microbes in the rumen. A cycle begins with the regurgitation of a rumino-reticular bolus followed by semi-circular jaw movements and ends with the deglutition (Jarrige et al., 1995). Rumination routines are influenced by pasture quality, intake quantity especially in fibrous content (Jarrige et al., 1995; Fustini et al., 2011), physiological status and the level of stress and anxiety of the animal (Soriani et al., 2012; Braun et al., 2013). In dairy cows, high-yielding individuals are fed high level of concentrates leading to a low level of insoluble fibre intake. This low level of fibre puts them at risk for both acute and chronic acidosis since it induces a decrease in the duration of the rumination in the daily cycle (De Vries et al. 2009). Characterising rumination is therefore an interesting indicator of health and welfare in ruminants.
Recent developments in sensors technology lead to their possible use for automated detection of domestic ruminants' main behaviours, such as rumination or grazing using mainly GPS and accelerometers (Swain et al., 2008). The present work aimed at developing a white-box approach to detect differences in rumination patterns in order to enable its accurate monitoring based on signal processing of a mobile device's IMU fixed on cows.

Material and methods

Two red-pied dry cows were fitted with an iPod Touch 4G or an iPhone 4S on their neck. Nine recording sessions were performed between September 2012 and November 2013: 7 with the cows grazing a rye grass-white clover pasture, 2 in stables when cows were fed silage-based diets. Each session included: (1) 100Hz data acquisition from the 3-D accelerometer and the 3-D gyroscope of the IMU by means of Sensor Data software (Wavefrontlabs), and (2) simultaneous video recording of the cows to allow accurate observation of the behaviours and their decomposition as sets of movements of the head or the

jaw. The dataset was divided in 2 independent sets, one for calibration (the 3 first fields' data) and one for validation of the procedure (the 6 other data).
The data analysis included 2 steps and was performed using Matlab R2013a. The first task was to create an algorithm for the detection of the main behaviours: grazing vs. ruminating vs. other. This algorithm was based on criteria from the movements' decomposition on 3D-accelerometer and gyroscope signals. The results of the classification were compared with the observed behaviours on the validation dataset to calculate the detection accuracies. The second part of the work focused on rumination. The duration and the number of bites were counted on the video files. The interesting IMU signal, chosen according to the most discriminative movement for the rumination process, was analysed on time and frequency domain using fast Fourier transform (FFT) and its inverse. A first filtration process was performed by choosing the most recurrent frequency between 1Hz and 6Hz to eliminate noise waves from the raw data to bring out the actual signal from rumination. Two algorithms were developed to characterize the deglutition and the mastication (number and duration of deglutition, number and duration of bites). The deglutition was described as a pause between two bouts of mastication (mobile standard deviation of a 2s sample of the selected signal<0.03rad/s at deglutition) while the mastication was known by its duration ranging between 15s and 60s. For the mastication bouts, a second filtration between 1 and 2Hz corresponding to normal frequency of bites during rumination was done. The number of mastication is counted with the number of zero crossing waves on the filtered signal.
The foreseen results were compared with the observed data from the validation dataset.

Results and discussion

The detection accuracies for the grazing and rumination ranged between 90% and 100% on pasture and between 80% and 84% in stable. The worse detection in stable is probably due to the different ration fed to the cows.
The rumination process was analysed using the rotation rate signal along the x-axis of the mobile device which is aligned with the cows nose to tail axis. This signal shows the particular jaw movement of the cattle during rumination best, showing a discriminant peak between 1 and 2Hz on the frequency domain (fig.1). This behaviour is characterized by succession of 32 to 48s of mastication and 2 to 4s of pause for deglutition. As shown in the fig.2, correct measurements were high for both duration and number of mastication in which over estimation is not respectively greater than 7s and 7 bites for fields' data. For the number of mastication, a bite corresponds to four zero crossing waves. The average mastication rate equals to 1.06 ± 0.06 bites/s. For the stable sessions, the correct measurement yielded from the field data was much lower. The deglutition's standard deviation is lower than 0.03rad/s. The duration of mastication is also more scattered (between 15s and 40s). This situation is explained by the difference of the diets fed to the animals and requires further data processing to improve the algorithm.

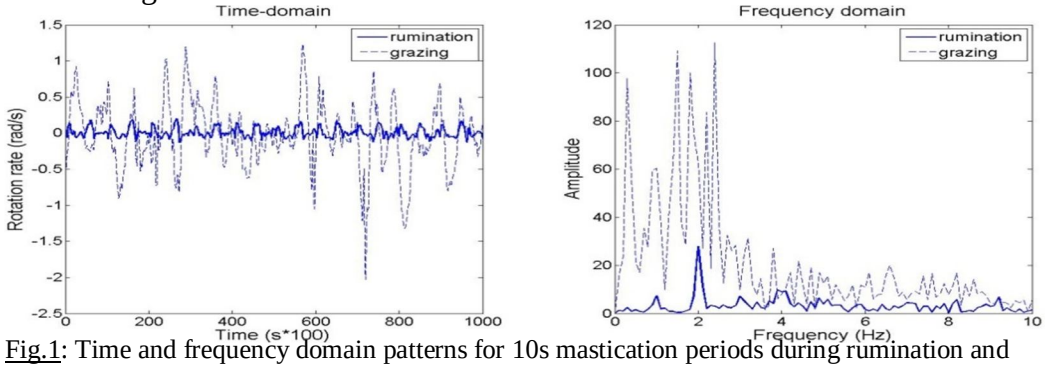

Fig.1: Time and frequency domain patterns for 10s mastication periods during rumination and grazing for field data along rotation rate on x-axis

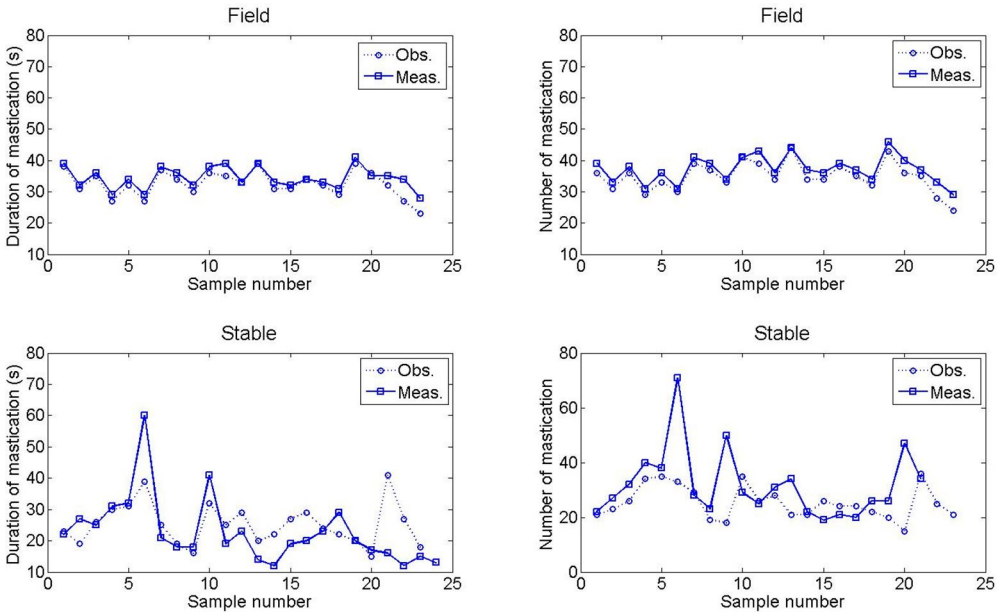

Fig.2: Comparison between the observed and the measured duration and number of mastication for field and stable validation data

Conclusion

The signals recorded from the IMU of iPhones and iPods offered an accurate detection of the behaviours of cattle. Deeper analysis about the rumination could measure its principals' characteristics such as the duration and the number mastication but the approach requires further improvements to account for major changes in rumination patterns induced by differences between pasture and silage-based diets.

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