Development of a multi-sensor and multi-application device for monitoring indoor and outdoor sheep behaviour

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Abstract

In ruminant behavioural research such as the investigation of feeding and social behaviours in the barn or at pasture, limits in data recording are based on (1) the difficulties both in simultaneously recording several different variables on a given animal and a great number of data for each one, (2) the interference between animal behaviour and the presence of the observer and finally (3) the time-consuming aspect of data acquisition and analysis.

Our objective was thus (1) to develop a recording device, either embedded on the animal or installed in fixed positions in the barn, capable of synchronising multiple sensors to characterise sheep behaviour and physiology parameters in their feeding and social environments, and (2) to design algorithms to automatically process these signals.

In collaboration with the Effidence start-up specialised in robotics, we designed a monitoring platform integrating a set of sensors able to record animal tracking (GPS, rangefinder), feeding activity (accelerometer, gyroscope, video camera, microphone) and emotional reactivity (heart rate sensor). Software was developed to allow for synchronous visualisation and real-time processing of the signals, and to extract characters of biological interest (e.g. time-budget) from automatically detectable states.

This upgradable and adaptable plug-and-play device, designed to allow for changes in sensors according to research requirements, constitutes a promising experimental tool to develop new PLF (Precision Livestock Farming) means/resources which now requires further developments in terms of miniaturization and validation.

Keywords: monitoring, multi-sensor, behaviour, sheep

Introduction

The methods based on visual observation are generalized to investigate feeding and social behaviours of herbivores. Nevertheless they are not adapted when high sample rates are necessary or when the risk of interference between animal behaviour and the observer is high. Some commercial solutions do exist but only give access to a limited number of sensors that have already been positioned and set, for instance on a collar (Thompson *et al.* 2012). In wildlife study, biologging technology is also widely developed (Ropert-Coudert and Wilson, 2005). Our objective was thus (1) to develop a recording device, either embedded on the animal or installed in fixed positions in the barn, capable of synchronising multiple sensors to characterise sheep behaviour and physiology parameters in their feeding and social environments, and (2) to design algorithms to automatically process these signals.

Material and methods

In collaboration with the Effidence start-up specialised in robotics, a monitoring platform was designed (figure 1). It was composed of two autonomous central units dedicated to data logging and a tablet for remote control. The sensors were either embedded on a sheep or placed in its environment to record animal tracking (GPS, 1D-infrared rangefinder), feeding activity (accelerometer, gyroscope, magnetometer, video camera and microphone) and emotional reactivity (heart rate sensor). The Effibox software (Effidence, France) was used to synchronise all data acquisition. Several experiments were conducted at pasture.
The Effibox-Qt platform was used (1) to visualize all the data in a synchronized manner and to choose the signals of interest and (2) to develop the dedicated algorithms (C++ language) for post-processing the signals. Thus a set of characters of biological interest (e.g. time-budget) were extracted from automatically detectable states (e.g. sheep is standing, walking or running, its head is up or down, active or inactive). These states were compared to a set of behavioural states (e.g. sheep is foraging, moving, standing, etc) that were manually obtained from video and audio data using The Observer XT (Noldus, The Netherlands). These were considered as “gold standard” and compared to those obtained with the automatic way (Spink *et al.* 2013).

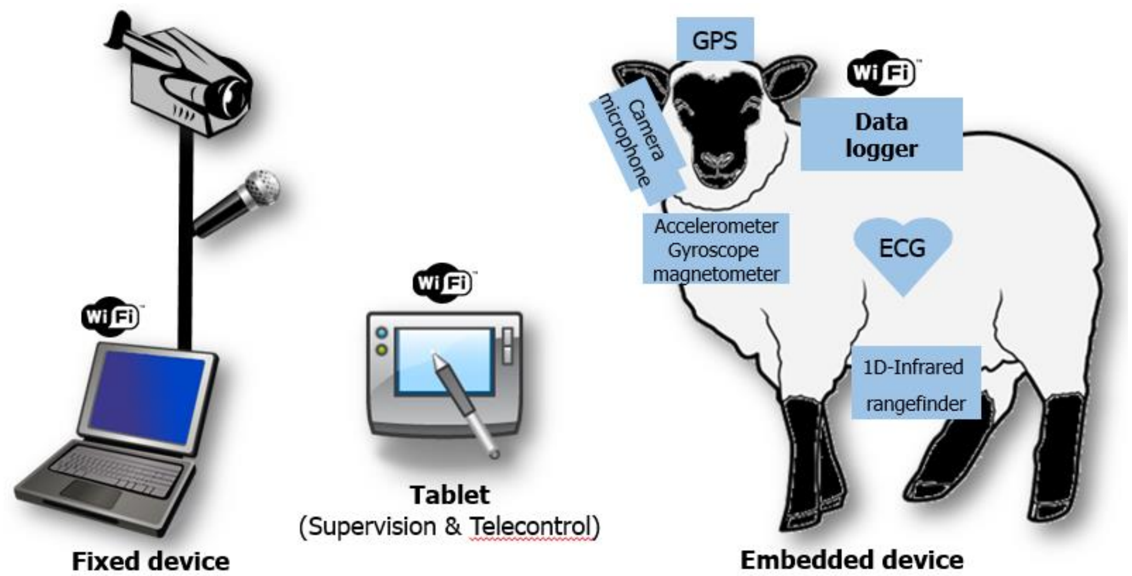

Figure 1: general view of the monitoring device. The three units (the tablet, the fixed and the embedded device) are wireless connected and the sensors wire connected.

Results

Several data sets were obtained with the embedded device at pasture from August 2013 to June 2014 and for a maximum duration of 6 hours. The data rate was considered acceptable (about 5 Giga bytes per hour), only video and audio files were on-board compressed. Data quality and availability was considered visually very good (figure 2) for all sensors except for the electrocardiogram (ECG) signal which was not exploitable in more than 50% of cases due to bad positioning of electrodes or interference with electromyogram signal (e.g. when animal is running).

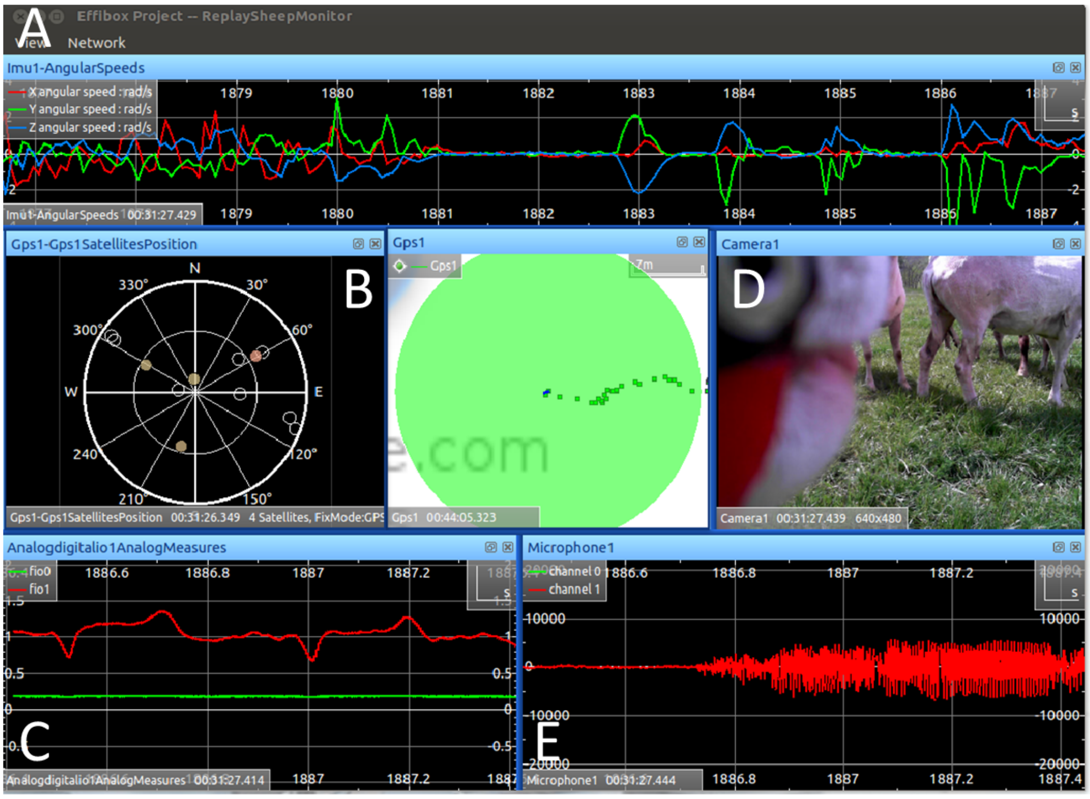

Figure 2: replay of all sensors with the Effibox software. Signals from inertial measurement unit (A) give information on animal agitation and the relative position of its head, GPS (B) gives information on absolute position and track, analogous signals (C) give information on heart rate (red) and relative distance to ground (green), video camera (D) gives information on diet and social interaction, microphone (E) gives information on vocalization and mastication. All this information is synchronised with a delay of under 100 ms.

The time for processing the different signals in order to obtain automatic states was about 2s for one hour of data whereas its needs about one hour for manually coding the behaviours in a one hour audio-video file. The duration of some behaviours (e.g. “gold standard – foraging”: 25% per hour) was much closer to the duration of the automatic states (e.g. “head down + active”: 23% per hour). Nevertheless we also obtained significant differences in some behaviours (e.g. “gold standard - moving”: 23% *vs* “automatic states: walking + running”: 13%). Here, our pedometer algorithm was not able to detect very slow movement of the animal and consequently underestimates the movement duration.

Conclusions

This paper proposes an upgradable and adaptable plug-and-play monitoring device able to interface a lot of sensors that may be judicially positioned on the animal and its environment according to research requirements. It constitutes a promising experimental tool to develop new PLF (Precision Livestock Farming) means/resources which now requires further developments in terms of miniaturization and validation.

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