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Dynamic cattle behavioural classification using supervised ensemble classifiers

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ABSTRACT

In this paper various supervised machine learning techniques were applied to classify cattle behaviour patterns recorded using collar systems with 3-axis accelerometer and magnetometer, fitted to individual dairy cows to infer their physical behaviours. Cattle collar data was collected at the Tasmanian Institute of Agriculture (TIA) Dairy Research Facility in Tasmania. In the first stage of analysis a novel hybrid unsupervised clustering framework, comprised of probabilistic principal component analysis, Fuzzy C Means, and Self Organizing Map network algorithms was developed and used to study the natural structure of the sensor data. Findings from this unsupervised clustering were used to guide the next stage of supervised machine learning. Five major behaviour classes, namely, Grazing, Ruminating, Resting, Walking, and other behaviour were identified for the classification trials. An ensemble of classifiers approach was used to learn models of cow behaviour using sensor data and ground truth behaviour observations acquired from the field. Ensemble classification using bagging, Random Subspace and AdaBoost methods along with conventional supervised classification methods, namely, Binary Tree, Linear Discriminant Analysis classifier, Naive Bayes classifier, k-Nearest Neighbour classifier, and Adaptive Neuro Fuzzy Inference System classifier were compared. The highest average correct classification accuracy of 96% was achieved using the bagging ensemble classification with Tree learner, which had 97% sensitivity, 89% specificity, 89% F1 score and 9% false discovery rate. This study has shown that cattle behaviours can be classified with a high accuracy using supervised machine learning technique. As dairy and beef systems become more intensive, the ability to identify the changes in the behaviours of individual livestock becomes increasingly difficult. Accurate behavioural monitoring through sensors provides a significant potential in providing a mechanism for the early detection and quantitative assessment of animal health issues such a lameness, informing key management events such as the identification of oestrus, or informing changes in supplementary feeding requirements.

1. Motivation

The health and general wellbeing of cattle can often been monitored and determined by cow behaviour patterns (Martiskainen et al., 2009; González et al., 2015). The physical behaviour of cows has been reported to be an early detector of diseases such as lameness (von Keyserling et al., 2011) and an indicator of pain (Gonzalez et al., 2010), heat stress (Allen et al., 2012) and social interaction within a herd (de Lauwere et al., 1996). Behaviour changes when animals are ill can include decrease in exploratory activity, reproductive activity, food and water intake, grooming and other social behaviours. At present, the productivity of dairy and beef industries is often restricted by management decisions being made for the herd as a single entity. Monitoring individual cows for key management decisions such as the identification of oestrus is too labour intensive. Systems that composed of motion sensors and analytic models have been designed to move toward the ultimate goal of precision cattle management. Precision management of herds can potentially be used to monitor the health and wealth of individual animals or identify the need for management intervention. In scientific studies with cattle, the use of behavioural baselines are often satisfied by human observation, a very time consuming and difficult task which is prone to

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human error and uncertainty. More recently cattle collar technologies with multiple sensors have been fitted to cows to monitor behaviour as shown in Fig. 1. The sensor observations acquired from the cattle collars are transmitted through low cost telemetry and stored to enable analytic models to infer animal behaviour. Previous work has shown that analytical models can utilise motion sensor observations in order to infer behaviour. Such models, however, have only shown success in classifying a limited number of behaviour types (González et al., 2015; Robert et al., 2009; Nielsen et al., 2010; Ungar et al., 2005).

Consequently, there is a need to develop analytic models that make cattle behaviour classification more accurate, robust and universally reusable. In this paper, a machine learning based analytics framework has been proposed to improve the accuracy of cow behaviour classification. One of the major challenges with behaviour modelling is that the sensor data acquired from collar systems is often noisy, due to sensor malfunction (Sikka et al., 2007) and the physical movement of the collar upon the animal causing sensor reorientation. The novelty of this research was to apply an ensemble based learning approach to find a set of machine learning classifiers, which could improve upon the accuracy of a single classifier system that has commonly been employed across a range of different applications (Fu et al., 2011; Seyerlehner et al., 2008; Briggs et al., 2009; Ordnez et al., 2011; Trunk, 1979; Jiminez and Langrebe, 1998; Niebles et al., 2008).

2. Problem space

Whilst cattle behaviours can be classified into many behaviours (Martiskainen et al., 2009), it was important to aggregate the problem space into a smaller set of discriminative classes given highly correlated, overlapping behavioural patterns could reduce the accuracy of the classification system. Whilst it would be possible to develop a specific behaviour classifier for an individual cow, building a general classifier that could be applied to any cow upon a farm was the most challenging problem to solve (González et al., 2015; Martiskainen et al., 2009). Hence, it was the primary objective of this work.

From the knowledge accrued from the cattle behaviour monitoring experiments, it is evident that if we combine particular classes such as {'Searching' and 'Walking'}, {'Chewing' and 'Ruminating'} from a larger group of ten behaviours, the problem space can be simplified into a classification problem of five behavioural types. This assumption was validated using unsupervised hybrid clustering analysis. The five behaviour classes and their respective sample size within the data set are listed in Table 1. In the next stage of this study, classifiers were trained and tested using cattle collar data and various classification experiments were conducted to establish the generalisation power of the classifiers.

3. System and experimental data

This study was conducted on 24 Holstein–Friesian cows from the Tasmanian Institute of Agriculture Dairy Research Facility at Elliott, 41°5′S, 145°46′E. Two groups consisting of 12 cows were established and balanced for means and variances (±SD) of milk production (25.0 ± 3.9 l per day), days in milk (71 ± 9 days), body weight (480 ± 34 kg), and age (4.6 ± 1.9 year). Each group of cows was allocated to one of two concentrate feeding levels. Cows received 50% of their concentrate feed allocation of 6.0 or 0 kg DM/day of Coprice® Dairy Pellets (CP = 14% of DM; ME = 12 MJ ME/kg of DM) twice daily during milking via automatic feeders (ALPRO System, Alfa Laval Agri, Sweden). Cows were milked twice daily through a herringbone parlour at approximately 0630 and 1530 h. Milk yield for each cow at each milking was recorded using Delavals Alpro Herd management System (DeLaval, 2014). Feeding treatments commenced on the 25th of October 2012 and ceased on the 31st December 2012. Pastures grazed were predominantly perennial ryegrass and cows were rotationally grazed as one herd, with daily forage allocation allowance of approximately 30 kg DM/cow/day of feed on offer above ground. Between the dates of the 28th November 2012 and 7th December 2012, cow grazing behaviour was intensively monitored. Grazing behaviour data was recorded via the digital application WhatISee (Heuser, 2014). These observed behaviours were categorised as grazing, searching (defined as head down and walking), walking (defined as head up and walking), ruminating, resting, chewing, head down, obstructed view, scratching or grooming and other (drinking or urinating). Behaviours were monitored during the 2 h period immediately following morning milking (M), between 12:00 pm and 2.00 pm (L) or during the 2 h period immediately following afternoon milking (A). Each of the 24 cows was monitored at least once (mostly twice) during each of three observational periods. Each of the 24 cows was fitted with a sensory collar. The WSN enabled location and behaviour monitoring collars (Wark et al., 2007) had a 20-channel GPS receiver chip (U-Blox5 – U-Blox, Thalwil, Switzerland), an active GPS antennae, a microcontroller (Atmel ATmega 1281v, California, USA) and 915 MHz transceiver (Nordic nRF905, Oslo, Norway), 4 alkaline D-cell batteries connected in series (Duracell, Australia), a 4 GB micro SD card (SanDisk, California,

Fig. 1. (a) Cow 16 at the TIA Dairy Research Facility in Elliot, Tasmania, Australia. The sensor collar is attached around the cow's neck; (b) cattle collar sensor system for capturing motion patterns associated with behaviour.