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Categorising sheep activity using a tri-axial accelerometer

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ABSTRACT

An animal's behaviour can be a useful indicator of their physiological and physical state. As resting, eating, walking and ruminating are the predominant daily activities of ruminant animals, monitoring these behaviours could provide valuable information for management decisions and individual animal health status. Traditional animal monitoring methods have relied on labour intensive, human observation of animals. Accelerometer technology offers the possibility to remotely monitor animal behaviour continuously 24/7. Commercially, an ear worn sensor would be the most suitable for the Australian sheep industry. Therefore, the aim of this current study was to determine the effectiveness of different methods of accelerometer deployment (collar, leg and eartag) to differentiate between three mutually exclusive behaviours in sheep: grazing, standing and walking. A subset of fourteen summary features were subjected to Quadratic Discriminant Analysis (QDA) with 94%, 96% and 99% of grazing, standing and walking events respectively, being correctly predicted from ear acceleration signals. These preliminary results are promising and indicate that an ear deployed accelerometer is capable of identifying basic sheep behaviours. Further research is required to assess the suitability of accelerometers for behaviour detection across different sheep classes, breeds and environments.

1. Introduction

Behaviour can provide a useful indication of the physiological state of livestock (Frost et al., 1997). Observation of the individual animal's posture and locomotion is often the first step in determining its overall health and welfare (Moreau et al., 2009; Weary et al., 2009). If behaviour could be monitored continuously it would provide an objective measure of individual activity from which animal health and welfare could be inferred. However, behavioural assessment is difficult (Martiskainen et al., 2009) and until recently, animal activity has only been quantifiable through direct observation or video monitoring, both of which are labour and time consuming (Müller and Schrader, 2003; Trénel et al., 2009).

In a commercial context, the inspection of grazing ruminants needs to be conducted in a short period of time and as infrequently as possible to ensure operational efficiency (Edwards, 2007). One limitation with the conventional approach of direct observation is that it only provides a behavioural assessment over the period in which the animals are actually observed. The consequence of this is that the behavioural states being relied upon for health and welfare assessment (for example grazing activity or travelling) may not be actually observed during inspection. Furthermore, grazing livestock are often farmed under conditions where regular human monitoring is either physically impossible (e.g. inaccessible terrain) or not cost effective, making constant daily observation impractical (Moreau et al., 2009). As a consequence, animals can go uninspected for extended lengths of time. Sensors which can automatically measure the behaviour of animals have the potential to alleviate some of these issues (Blokhuis et al., 2010), and as such, interest in developing automated measures of animal behaviour has increased (Rushen et al., 2012).

One form of animal-borne sensing which has the potential to measure behaviour autonomously is accelerometer technology (Howell and Paice, 1989). Some accelerometers use the piezoelectric effect in which stresses on microscopic crystals (caused by acceleration) generate a measurable voltage. Alternatively the piezo-resistive effect produces a change in the material resistance due to stresses effected by acceleration, again which can be measured in an appropriate circuit (via a generated voltage). Another approach is where the acceleration may change the capacitance that exists between two microstructures in close proximity to one another other. All of these (and similar approaches) generate an electrical signal which may be converted into a measure of the accelerative activity along defined axes. This signal is generated by

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gravitational acceleration (static) and inertial acceleration due to movement (dynamic) (Brown et al., 2013). The use of accelerometers for studying organism movement originated in the 1950's to assess changes in human physical activity in relation to health status (Inman and Eberhart, 1953) and in greater detail throughout the 1970's (Morris, 1973). Mainly due to the miniaturisation of the technology, the past decade has witnessed an exponential rise in the amount of research on remote monitoring of animal behaviour through accelerometry (see reviews by Brown et al. (2013) and Shepard et al. (2008)).

For livestock, the capability of accelerometers to measure posture and activity states has been established in cattle (González et al., 2015; Martiskainen et al., 2009; Robert et al., 2009; Smith et al., 2015; Trotter et al., 2012), pigs (Ahmed et al., 2016; Ringgenberg et al., 2010), goats (Moreau et al., 2009) and sheep (Alvarenga et al., 2016; Marais et al., 2014; Mason and Sneddon, 2013; McLennan et al., 2015; Radeski and Ilieski, 2017). Tri-axial accelerometers were attached to the hind leg of fifteen crossbred calves at a sampling frequency of 100 Hz (Robert et al., 2009). Using classification trees to predict behaviour, lying and standing activities yielded an accuracy of 99.2% and 98% respectively whilst walking was significantly lower with an accuracy of 67.8% (Robert et al., 2009). Accelerometers attached to goats using a chest belt, dog harness and neck collar was tested by Moreau et al. (2009). Accuracies for the true recognition of activities were in the range from 87% to 93% for eating, 68% to 90% for resting and 20% to 92% for walking. Marais et al. (2014) deployed a 3-axis accelerometer on a collar, reported behavioural recognition accuracies of 87.1% and 89.7% using linear discriminant analysis (LDA) and quadratic discriminant analysis (QDA) algorithms, respectively. To date, studies which have deployed accelerometer sensors on sheep have used either leg, collar or halter mounted methods of deployment. Whilst these modes of deployment may be acceptable in a research context, from a commercial perspective, the most applicable industry acceptable standard is an ear-tag form factor which aligns with conventional husbandry practices. The results of previous research (Bikker et al., 2014; Wolfger et al., 2015) suggest ear deployed accelerometers show promise for monitoring behaviour in cattle. However, before this technology can be used to assess the behavioural patterns of sheep, validation studies are required.

The aim of this current study was to determine the ability of a tri-axial accelerometer to discriminate between the various movements in sheep. Noting the desirability of an ear-tag form factor (and hence deployment mode), the tri-axial accelerometers were mounted on collars, the front leg and on an ear-tag to classify basic sheep movements, namely standing, grazing and walking.

2. Materials & methods

2.1. Animals

This study was conducted at the University of New England's SMART Farm, Armidale, NSW, Australia (Longitude 151° 35' 40" E, Latitude 30° 26' 09" S). All animal experimental procedures were approved under the University of New England Animal Ethics Committee, AEC14-066.

A group of ten Merino x Poll Dorset ewes, approximately 11 months of age with an average weight of 62 kg (+/−5kg) were used in the present study. A subset of five animals were selected at random for instrumentation, with the remainder retained as companion animals.

2.2. Instrumentation

A GCDC X16-mini MEMS accelerometer (Gulf Coast Data Concepts, MS, USA) configured to collect signals at 12 Hz (12 samples/s) were attached simultaneously to three locations on candidate sheep: a neck collar, the anterior side of the nearside front shin and the ventral side of the offside ear. The sensors were 50 × 25 × 12 mm in size and weighed 17.7 g.

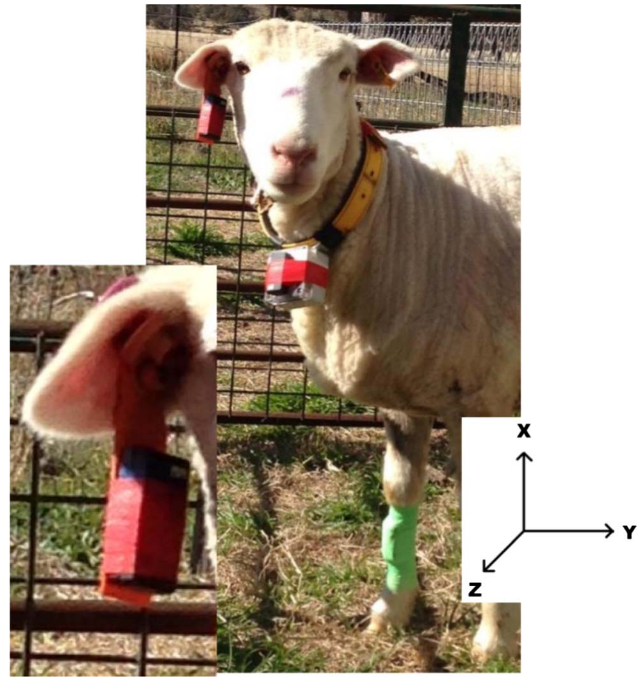

Fig. 1. Experimental animal displaying the three X16-mini accelerometer locations evaluated; ear, neck (collar) and right foreleg. Insert shows the axis orientation of the sensor.

The location and method of fixation for the sensors is shown in Fig. 1. Collar deployed accelerometers were attached to the polycarbonate case of a UNE Tracker II GPS collar (Trotter et al. 2010) and placed around the sheep's neck. Front leg mounted sensors were attached to the foreleg shin using Vetflex self-adhesive bandage. Whilst this method did not provide a completely rigid attachment and some movement of the sensor was observed this was not considered to be substantial. Previous research has used a similar method of attachment for sensors in dairy cows (Luu et al., 2013).

Ear-tag deployed sensors were attached to a trimmed management tag (Allflex) using electrical tape. They were placed in the central lower half of the animals' offside ear; consistent with normal ear tag deployment. This location is suitable to achieving a similar placement in all animals for synchronicity.

The GCDC X16-mini tri-axial accelerometer measures static and dynamic acceleration along three orthogonal axes (*X*, *Y* and *Z*). Orientations of the *X*, *Y* and *Z* axis in this current study were dorso-ventral, lateral and anterior-posterior, respectively (Fig. 1). Due to the limited number of accelerometers, only one animal was instrumented at a time. A single animal was randomly selected and restrained in a small catching pen. Accelerometers were deployed after which three animals (one instrumented and two non-instrumented) were released into a small adjacent paddock (80 m × 6 m) for visual observation for a period of approximately 2.5 h. This process was repeated on five different sheep.

2.3. Observations

Upon release, the movement of each instrumented animal was monitored and video recorded. The sheep were not disturbed during the first hour and were noted to perform mainly grazing and some resting behaviour. After the first hour, animals were walked up and down a laneway for approximately 15 min. This period of walking was often followed by a 15–20 min period of standing behaviour without walking, then a mixture of standing and grazing. Observations were classified as listed in Table 1. Accelerometers and video observation files were