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Predicting bull behavior events in a multiple-sire pasture with video analysis, accelerometers, and classification algorithms

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A B S T R A C T

Parentage data from beef calves has shown that in multiple-sire pastures a disproportionate number of calves are born from a single bull. Investigating and accurately quantifying bull behavior within multiple-sire pastures will begin to determine reason(s) for the variability in the number of calves sired. The study objective was to assess accelerometer data and various classification algorithms to accurately predict bull behavior events in a multiple-sire pasture. Behavior events of interest in this study included lying, standing, walking, and mounting.

Two bulls and ten estrous synchronized cows were used. True behavior events were determined during daylight hours with video analysis, and matched with accelerometer data. Accelerometers were attached to both ears, withers, and neck of both bulls. Accelerometer data were recorded for every second over 3 days. Accelerometer data were used to generate algorithms and accuracy was evaluated compared to known video behavioral data.

The prevalence based on the raw video data for lying was 32.6%, standing was 59.4%, walking was 7.4%, and mounting was 0.6%. The random forest classifier had the highest accuracy compared to other classifiers (random tree and decision tree) for each tag location and behavior of interest. The accuracies from the random forest algorithms ranged from 92 to 99% for lying, 85 to 90% for standing, 73 to 77% for walking, and 74% to 80% for mounting. The classification algorithm was able to accurately predict a lying and standing event, and predict a walking and mounting event with a lower accuracy. Further research is needed to determine how behaviors between bulls affects overall parentage data.

1. Introduction

Bull behavior can influence overall conception rates in multiple-sire pastures (Blockey, 1979). Libido, the willingness for a bull to breed a cow, and serving capacity have been identified as factors influencing fertility and conception rates in pasture breeding operations (Blockey, 1978; Chenoweth, 1981; Crichton and Lishman, 1988). The purpose of utilizing multiple bulls in a breeding pasture is to increase overall fertility and calving rates in a herd and reduce the number of pastures required compared to a single sire pasture breeding program. Once a bull services a female, she needs to conceive, maintain the pregnancy, and have a viable calf. If a particular bull is not actively breeding cows or the act of mating does not result in a successful pregnancy, then that bull is not contributing to the overall productivity of that herd.

Parentage data from beef calves has shown that in multiple-sire pastures a disproportionate number of calves are born from a single bull (Fordyce et al., 2002; Holroyd et al., 2002; Van Eenennaam et al., 2007). The disproportionate parentage distribution shows that not all bulls are contributing equally to the number of calves being sired on the operation. Successful investigation of the factors influencing the variability in the number of calves born per bull requires accurate ways of quantifying bull behavior in a multiple-sire pasture. Previously, quantifying bull behaviors in a

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multiple sire pasture involved visual observations of the desired individual behaviors (Blockey, 1979; Boyd et al., 1989). Visual observation is labor intensive, increases the chance for human error by missing behavioral events in a given time period, and can influence the behavior of animals through human interaction (Theurer et al., 2013). Some investigations using visual observation to quantify bull behavior have been performed in controlled settings, such as small pens or within a limited time frame, e.g. 20 min (Carpenter et al., 1992; Whitworth et al., 2008). The use of technology provides new tools to assess behavior accurately while decreasing the need for human observations, as well as increasing the time frame that animal behavior can be monitored.

Accelerometers can be used to assess lying and standing behaviors in cattle (Robert et al., 2009; Theurer et al., 2013). Using accelerometers to record specific behaviors of cattle in beef cow-calf herds in real-time provides advantages when investigating the bull's role and behavior in the reproductive efficiency of that operation. Understanding a bull's overall activity throughout a breeding season can be used to predict his contribution to the overall calving rate. It is hypothesized that actively breeding bulls will spend more time standing, walking, and mounting and less time lying compared to bulls not mating as many females. The study objective was to assess accelerometer data and various classification algorithms to accurately predict bull behavior events for lying, standing, walking, and mounting in a multiple-sire pasture.

2. Materials and methods

2.1. Animal population

All procedures were approved by the institutional animal care and use committee of University of Nebraska-Lincoln (IACUC # 1124). Two bulls, aged 3 years old were used in the project. One bull was Angus (designated bull #2) and the other was a composite of Red Angus, Simmental, and Gelbvieh (designated bull #1). Both bulls were placed in a rectangular pasture with 10 estrus-synchronized crossbred cows for three days (6/22/16–6/24/16). Three observations days were chosen due to the time period expected for cows to exhibit signs of estrus from estrus synchronized using the select-synch protocol (Patterson et al., 2003). All the cows exhibited signs of estrus during the observation period. The pasture was enclosed with electrical fencing and was 280 by 180 feet. A single movable oval water trough was placed in the pen and a rectangular feed bunk was used to provide ad libidum access to grass hay.

2.2. Accelerometer data collection

Accelerometer data were recorded with the use of Smartbow ear tags (MKW Electronic GmbH, Weibern, Austria). Accelerometer data recorded the three-dimensional location (x, y, and z axis) of each tag during each second of the study duration. Ear tags were attached to both bulls in four difference locations, the left and right ear, the withers, and the neck. Smartbow tags were attached to collars that fit around each bull's neck and were attached to each bull's wither with the use of glue, netting, and a cloth patch, and were attached to each ear with a button tag (Fig. 1).

2.3. Video analysis

Cameras (Axis Communications, Lund, Sweden) were attached the southwest and northeast corner of the pasture. The cameras were programmed to record activity of all cattle within the pasture in the camera frame, and to provide a one-second interval timestamp during the 3 day trial. The camera time stamp was synched with the accelerometer time stamp at the start of the study to record data at the exact same hour:minute:second.millisecond.

With the use of only two cameras within the rectangular pasture, there were areas in the pen both bulls could be out of frame throughout the recording period. Video data were watched by a single investigator (KA) and logged (Noldus- Observer XT 11, Leesburg, VA) to quantify the exact onset time and duration of each behavior event by each of the two bulls. Behavior events of interest included lying, standing, walking, and mounting. Video recorded events were classified using the following definitions:

- *Lying* – Bull has all 4 legs tucked underneath the torso or lying on one side of its body for 1 s or longer. The lying period ended when the bull transitioned into another behavior.
- *Standing* – Bull has all 4 feet planted on the ground for 1 s or longer. Time spent grazing is included in this category, even if a small number of steps are taken during the grazing period. A period of time classified as standing ended when the bull transitioned into another behavior.
- *Walking* – Animal has taken 3 steps in a progressive direction, this behavior ends when the progressive movement stops.
- *Mounting* – Mounting event begins when the front feet of the bull leaves the ground, and ends when the front feet are back on the ground. During the mounting period, the animal being mounted stands in place during the mounting event in order to be bred.
- *Out of frame* – The bull is no longer visualized by either camera placed in the northeast and southwest corners of the pasture.
- *Other* – The bull does not display a defined lying, standing, walking, or mounting behavior.

Each event was mutually exclusive, meaning a bull identified as exhibiting one behavior could not simultaneously be classified as exhibiting another behavior. Each bull's behavior was recorded independent of the other bull's behavior.

2.4. Data preparation

Data from the accelerometer and video were exported as Excel spreadsheets (Microsoft Corp., Redmond, WA). Spreadsheets were imported into KNIME Analytics software as CSV files. Data were matched between the accelerometer and video log for each second of the study in order to create a combined dataset. The combined dataset was partitioned into ear, wither, and neck sub-groups. The two ear tags were combined into a single dataset. Binary variables was created for each behavior of interest (lying, standing, walking, and mounting) and assigned a value of 1 (behavior occurred) or 0 (behavior did not occur) for each second of each sub-grouped dataset.

The prevalence for each behavior of interest (lying, standing, walking, and mounting) based on raw video data was determined by combining the number of video-recorded events for the four behaviors of interest for both bulls divided by the total number of behavior events. Behaviors logged 'out of frame' and 'other' were not included in the prevalence analysis for the raw video data. The final dataset used to build the algorithm included bull identification, accelerometer tag number, behavior onset time, behavior, and the x-axis, y-axis, and z-axis accelerometer readings. A flow diagram of data preparation, refinement, partitioning, and classification is shown in Fig. 2.

2.5. Variable preparation and creation

Variables were created in order to increase the predictive accuracy of each behavior event. Multiple variables were created with the raw accelerometer data recordings for the x, y, and z, axis.