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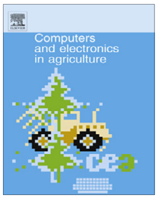

Application note

The use of image analysis to determine the number and position of cattle at a water point

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ABSTRACT

This study assessed the application of an image analysis method to accurately determine the number and position of cattle which are critical inputs for enteric methane emission calculations using micrometeorological methods. Animal imagery was collected with three synchronised time-lapse cameras located at 7, 35 and 77 m from a 20 × 30 m water point enclosure containing 20 steers, recorded over three consecutive days. Four independent observers counted the number of animals visible in each of 516 images. The counting error increased with distance from the enclosure (0.1%, 3.7% and 15.4% of total animals) as a result of increased overlapping and decreased clarity of the animals on the image. Animal positions were estimated using a polynomial transformation of image coordinates (pixels) to map coordinates. The average location error (distance between estimated and actual position) of independent targets was 0.8 ± 0.5 m and did not change with distance to the camera. We conclude that the analysis of 12 MP images from time lapse cameras can provide reliable and accurate estimates of the position and the number of animals located within 55 m from the camera.

1. Introduction

Cattle typically gather around water points to drink water, rest and ruminate for up to 6 h per day particularly in rangeland systems (Tomkins et al., 2009). This behaviour provides opportunities to measure enteric methane emission using micrometeorological methods. Depending on the technique used, animal numbers or animal positions are critical inputs to the emission calculations (McGinn et al., 2011). Global Positioning System (GPS) devices are widely used for tracking cattle in the field. However, the high cost per unit, limited lifespan of batteries, data loss due to equipment breakage and loss of satellite reception are disadvantages of these devices (Swain et al., 2011). While some studies report that GPS collars obtained a positional fix on 99.9% of the attempts (Trotter et al., 2010) other authors have reported poorer performance of their units; for example, Tomkins and O'Reagain (2007) indicated that only seven of their 12 units provided sufficient data for spatial analysis of animal distribution. Also, Tomkins et al. (2009) reported that the animal positional data from one deployment of their GPS collars was incomplete to such an extent that it could not be used to determine spatial patterns of activity. Loss of satellite reception and battery failures were identified as causes of the intermittent data loss (Tomkins and O'Reagain, 2007).

The background for this work was the study of enteric methane emitted by grazing cattle. The eddy-covariance technique we used (Harper et al., 2011) requires animal position information. Our attempt to use GPS collars for this purpose was not successful, as the positional data from the collars was not comprehensive enough for accurate calculations (e.g., over a 15-min measurement one "missing" animal can lead to a large error in calculated emissions). A time-lapse camera system was thus examined as an alternative to the GPS collars. The purpose of this work was to assess the accuracy of animal counts and positions using the proposed image analysis method.

2. Materials and methods

This study was conducted over 3 consecutive days from 24 to 26 September 2014 at the CSIRO Lansdown Research Station

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(146°45′E, 19°40′S) located near Townsville, in North Queensland, Australia. Two separate tests assessed the accuracy of animal counting and positions.

2.1. Test 1: accuracy of animal counting

Three time-lapse capable cameras (GoPro 3+ black edition, GoPro, San Mateo, CA, USA) were mounted at a height of 9 m on individual aluminium masts positioned 7, 35 and 77 m from the edge of a 20 × 30 m water point enclosure (Fig. 1a). One entry gate and one exit gate allowed access to an adjacent 15 ha paddock. The cameras operated on 12 V batteries charged with solar panels. In time-lapse mode, the interval time can be programmed from 0.5 to 60 s and the captured images can be saved at a resolution of 5, 7 or 12 megapixels (MP). For this study, each camera was configured to take a 12 MP wide-angle image every 10 s. Clocks and start times for each camera were synchronised and images were stored on a 64 GB micro SD card which was downloaded each day. Over three consecutive days of animal monitoring, 20 brahman cross steers congregated within the enclosure between 9:30 am and 3:00 pm. Within these periods one image every 5 min was selected and 4 independent observers estimated the number of animals in each of 516 images (172 synchronised images per camera). The counting error (CE) was calculated as:

$$\mathrm{CE} = \mathrm{ANA} - \mathrm{ENA}$$

where ANA = actual number of animals (20 animals) and ENA = estimated number of animals.

The position of the animals was measured using 172 images taken by the camera closest to the enclosure. Two measures of animal dispersion were calculated from their positions: The group dispersion was calculated as the average distance of all animals to the average group position. The nearest neighbour dispersion was calculated as the average distance of all animals to the nearest neighbour.

2.2. Test 2: accuracy of position estimates

The positional coordinates of the animals were calculated from a polynomial transformation of the image coordinates (Chen and Hill, 2005). This is a simple statistical fit of known x, y grid coordinates (targets in the image) to the image coordinates (pixels) using polynomial regressions. Forty two fixed targets were arranged in three parallel lines of 14 targets per line to form a rectangular grid of 40 × 113 m (Fig. 1b). These dimensions were chosen to allow all targets to be captured in the images. Target positions in the grid were assigned x and y coordinates that varied from 0 to 40 m and 0 to 113 m respectively. A tower, with a GoPro 3+ black edition camera mounted at 9 m height, was located at 7 m away from one of the short sides of the grid and 12 MP photos of the grid were taken. The vertical and horizontal field of view were 94.4° and 122.6° respectively. The pixel coordinates of each target were recorded using ImageJ software (http://rsb.info.nih.gov/ij/). Twenty one of the 42 targets were then used to derive the following 7-term polynomial equation relating pixel coordinates (x_p, y_p) and grid coordinates (x_{Grid}, y_{Grid}):

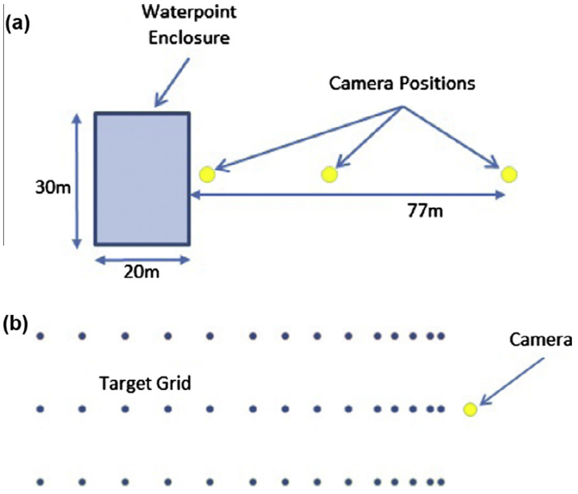

Fig. 1. Representation of the relative position of the cameras, water point enclosure and target grid for: (a) test 1 and (b) test 2.

$$x_{Grid} = a_0 + a_1 x_p + a_2 y_p + a_3 x_p y_p + a_4 x_p^2 + a_5 y_p^2 + a_6 x_p^2 y_p + a_7 x_p y_p^2$$

$$y_{Grid} = b_0 + b_1 x_p + b_2 y_p + b_3 x_p y_p + b_4 x_p^2 + b_5 y_p^2 + b_6 x_p^2 y_p + b_7 x_p y_p^2$$

where p = pixel, and the parameters a_i and b_i are best-fit regression coefficients.

To maximise the accuracy of the estimates the grid was divided in three zones and one set of equations was calculated for each zone using 9 targets per zone. The x_{Grid} for all zones extended from 0 to 40 m and the y_{Grid} for zone 1 (closest to the camera), 2 and 3 ranged from 0 to 18 m, 18 to 53 m and 53 to 113 m respectively.

The position of the remaining 21 targets (minimum of six targets per zone) provided a test case, where the positional error was calculated as the distance between actual and estimated positions of these targets.

2.3. Statistical analysis

Animal counts were averaged over half hour periods, resulting in 28 measurements (three days) for each combination of observer and camera position. Such averaging resulted in observations which could be reasonably assumed to be independent, though this assumption was assessed by examining the autocorrelation between successive periods. The data were subject to analysis of variance, with a blocking structure of half-hour periods nested within days and individual counts nested within half-hour periods, and a factorial treatment structure of observer by camera position. Group and nearest neighbour dispersions were included as potential covariates in the analysis. A plot of residuals vs fitted values, together with examination of the variability for the three camera positions, indicated that the variance increased with the mean; therefore, a log transformation was applied to satisfy the assumption of homogeneity of variance. An increment of 0.5 was added before transforming, because of the zero observations. Least significant differences (at the 1% level) were used to compare pairs of means on the log scale. Regression analysis was used to assess the relationship between distance to camera and positional error for test 2. All the analyses were conducted using GenStat (http://www.vsni.co.uk/products/genstat/).

3. Results and discussion

3.1. Test 1: accuracy of animal counting

For the cameras located at 7 m from the enclosure, the autocorrelation between successive half-hour periods was negligible, for cameras at 35 m it was small (<0.16) or negative, and for cameras at 77 m it was modest (between 0.20 and 0.47). The assumption of independence was therefore satisfied, and there was little to be gained by incorporating autocorrelation into the statistical model. Both group and nearest neighbour dispersion were highly significant when included without the other, but when both were