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Analysis of individual classification of lameness using automatic measurement of back posture in dairy cattle

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ABSTRACT

Currently, diagnosis of lameness at an early stage in dairy cows relies on visual observation by the farmer, which is time consuming and often omitted. Many studies have tried to develop automatic cow lameness detection systems. However, those studies apply thresholds to the whole population to detect whether or not an individual cow is lame. Therefore, the objective of this study was to develop and test an individualized version of the body movement pattern score, which uses back posture to classify lameness into 3 classes, and to compare both the population and the individual approach under farm conditions. In a data set of 223 videos from 90 cows, 76% of cows were correctly classified, with an 83% true positive rate and 22% false positive rate when using the population approach. A new data set, containing 105 videos of 8 cows that had moved through all 3 lameness classes, was used for an ANOVA on the 3 different classes, showing that body movement pattern scores differed significantly among cows. Moreover, the classification accuracy and the true positive rate increased by 10 percentage units up to 91%, and the false positive rate decreased by 4 percentage units down to 6% when based on an individual threshold compared with a population threshold.
Key words: lameness detection, dairy cattle, back arch, image processing

INTRODUCTION

Lameness, which can be defined as a deviation in gait to reduce pain (Scott, 1989), is the third most important health-related cause of economic loss in the dairy industry after fertility and mastitis (Booth et al., 2004). The loss can be measured in terms of decreased milk yield (Green et al., 2002; Archer et al., 2010), reduced reproductive performance (Sprecher et al., 1997; Garbarino et al., 2004), increased culling risk (Barkema et al., 1994; Booth et al., 2004), and increased production costs (Cha et al., 2010). Lameness is also a major welfare problem (Bruijnis et al., 2012) because it is a painful condition (Whay, 1997; Whay et al., 1998; Flower et al., 2008) that reduces mobility and prevents normal behavior (Singh et al., 1993). Early detection is therefore important for effective treatment and prevention.

Currently, diagnosis of lameness at an early stage in dairy cows relies on visual observation by the farmer, which is based on subjective scores called locomotion scores. Visual locomotion scoring is the most common method to obtain a prevalence rate (Flower and Weary, 2009). However, the visual scoring method is limited because it is sensitive to variations within and between observers (Thomsen et al., 2008; Channon et al., 2009). Visual locomotion scoring assesses alterations in the cow's gait and posture through qualitative parameters. Because differences exist in the walking patterns of each individual cow (Pluk et al., 2012), the effect of lameness on the measured variables cannot be considered identical for all cows. As are all living organisms, cows are complex, individually different, and time-variant dynamic (CITD) systems (Berckmans, 2008) and show lameness in different ways. The anatomy and posture of cows, for example, can affect a range of gait variables, such as stride length, back arch, position of the head, or speed (Flower and Weary, 2009).

Today, decision-making on commercial dairy farms is sensory-based and individual by measuring traits such as activity (Liu and Spahr, 1993), neck activity (Holman et al., 2011), individual feed intake (Halachmi et al., 1998), and milk properties (Tomaszewski, 1993). However, an individual approach has yet to be applied to detection of lameness.

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In the last 10 yr, a major research effort has been made to develop systems that automatically and objectively detect lameness. Different techniques have been applied, such as performance plus behavior analysis (Kramer et al., 2009), kinetic and kinematic analysis, and image processing. Kinematic analysis measures the geometry of movement, without considering the forces that cause the movement, and calculates different aspects of gait such as stride length, stance, and swing duration (Flower et al., 2005). Kinetic methods such as ground reaction force measurements (Rajkondawar et al., 2002) and a 4-balance weighting of each leg (Pastell et al., 2006) offer a means to assess lameness locomotion by evaluating load distribution to quantify the effects of lesions in the locomotor system. StepMetrix (BouMatic, Madison, WI), the only such product currently available commercially, is based on these kinetic principles; it measures the vertical ground reaction forces and position of the load exerted by cows while they are walking.

Computer vision techniques, on the other hand, offer the possibility to extract other variables such as step overlap (Pluk et al., 2010) and back posture (Poursaberi et al., 2010). They can be easily incorporated into existing farm system, are relatively inexpensive, and provide continuous information without the need for manipulating or placing a sensor on each animal.

However, all of these studies are based on a population-based model, that defines thresholds and criteria at the group level rather than focusing on the individual differences between animals.

Deviations in gait are only partly caused by pain associated with injuries on the hooves and limbs (Flower et al., 2008). According to Greenough et al. (1981), deviations can also be the result of factors such as damage in the locomotor system. Natural differences among cows, such as udder size, can further affect changes in walking gait and therefore result in individual differences among animals.

The hypothesis of this paper is that the variables to detect lameness are conditioned by large variation among individual cows and that, to be accurate, an automatic lameness detection system must account for this variation. Therefore, the hypothesis of this study is that an individual-based model that assigns thresholds for each animal would outperform a population-based model that defines a threshold for the whole herd.

The main objective of this study was to develop an image-based detection system that would allow us to apply the body movement pattern (**BMP**) on an individual level and that uses back posture to classify lameness (Poursaberi et al., 2011). The second objective was to compare both the population and individual approaches under farm conditions.

MATERIALS AND METHODS

Experimental Setup

Animals and Housing. The experimental data were gathered on a commercial dairy farm located in Yifat, Israel. The herd size of the farm was 951 lactating Holstein-Friesian cows with an average milk production of 11,500 kg/yr per cow. The cows were divided in 11 groups according to farm production requirements. The cows were milked 3 times a day in a 2 × 32 side-by-side parallel milking parlor. The last 2 milking groups, comprising 90 cows in total, were used for the experiment. After milking, which is the most suitable time to conduct gait assessment in dairy cattle (Flower et al., 2006), the cows were recorded while passing through a 4-m-wide, 7-m-long corridor with a concrete floor. To force the cows to create a single file, the alley was narrowed to 1.5 m wide with a mobile demountable fence of light tubular rails that were removed after every video session to avoid any further intrusion into the farm's routine and any interference with cow traffic (Figure 1).

Video Recordings. Videos were acquired from October 26 through December 21, 2011. During the first month, videos were recorded using a Canon 60D camera equipped with a Canon 17-85 IS USM lens (Canon Inc., Tokyo, Japan). During the second month, a Nikon D700 camera with a Nikon 28/105 AF Nikkor lens (Nikon Inc., Tokyo, Japan) was used. The cameras were positioned on a tripod at a height of 1.35 m perpendicular to the route of cow passage and 6.75 m away from the alley, which permitted a side view of the cows (Figure 2). Color videos were captured in QuickTime H.264 compressed format, with a frame rate of 25 fps at a resolution of 1,920 × 1,080 pixels. In total, the final database included 1,024 videos of cows with one expert score per video spread over a period of 14 d.

Scoring Methods. A veterinary expert on lameness visually scored all video recordings, using the 5-point locomotion score of Flower and Weary (2006). This scoring method is based on the observation of 5 gait attributes: flatness of the back, steadiness of head carriage, tracking up, asymmetry of the gait, and reluctance to bear weight. The criteria used to categorize cow locomotion are shown in Table 1. To increase the expert's reliability (Engel et al., 2003; O'Callaghan et al., 2003), the 5-point scoring scale was simplified into a 3-category scale. Scores 1 and 2 classified cows as not lame; score 3 classified cows as lame; and scores 4 and 5 classified cows as severely lame. The visual locomotion score was chosen as a gold standard (Dohoo et al., 2003) because of its practical application: it can be