BIOSYSTEMS ENGINEERING 133 (2015) 46–55

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

The automatic detection of dairy cow feeding and standing behaviours in free-stall barns by a computer vision-based system

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ARTICLE INFO

Article history:
Received 17 October 2014
Received in revised form
22 December 2014
Accepted 20 February 2015
Published online 18 March 2015

Keywords:
Cow behavioural activity
Precision livestock farming
Dairy farming
Vision techniques

Changes in cow behaviour may occur in relation to health disorders. In literature the suitability of using behavioural changes to provide an early indication of disease is studied. The possibility of achieving a real-time analysis of a number of specific changes in behaviours, such as lying, feeding, and standing, is crucial for disease prevention.

Cow feeding and standing behaviour detectors were modelled and validated by defining a methodology based on the Viola–Jones algorithm and using a multi-camera video-recording system to obtain panoramic top-view images of an area of the barn.

Assessment of the detection results was carried out by comparison with the results generated by visual recognition. The ability of the system to detect cow behaviours was shown by the high values of its sensitivity achieved for the behaviours of feeding and standing which were about 87% and 86%, respectively. Branching factor values for the two behaviours showed that one false positive was detected for every 13 and 6 well-detected cows, respectively. On the basis of these research outcomes, the proposed system is suitable for computing cow behavioural indices and the real-time detection of behavioural changes.

1. Introduction

In our previous study (Porto, Arcidiacono, Anguzza, & Cascone, 2013) a computer vision-based system (CVBS) for the automatic detection of the lying behaviour of dairy cows was proposed and validated in an experiment carried out within a cubicle free-stall barn located in the province of Ragusa, Italy. The CVBS was composed of a multi-camera video-recording system and a software component which included a cow lying behaviour detector based on an algorithm originally proposed by Viola and Jones (Viola & Jones, 2001, 2004). The ability of the CVBS to detect cow lying behaviour was confirmed by the high value of its sensitivity, which was approximately 92%. These results suggested that the system proposed in that study could be used for the calculation of the cow lying index which is widely used to investigate cow lying behaviour in free-stall barns. However, the method used to obtain the classifiers of

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http://dx.doi.org/10.1016/j.biosystemseng.2015.02.012

Nomenclature

BF	Branching Factor
CFBD	Cow feeding behaviour detector
CFI	Cow feeding index
CLI	Cow lying index
CSBD	Cow standing behaviour detector
CSI	Cow standing index
CVBS	Computer Vision-Based System
FN	False negative
FP	False positive
FPRcas	Minimum value of the false positive rate of the cascade
h	Height of the sliding window
H	Height of a positive image
H'	Height of the negative image selected by the operator
MF	Miss Factor
QP	Quality Percentage
TP	True positive
TPRcas	Minimum value of the true positive rate of the cascade
w	Width of the sliding window
W	Width of a positive image
W'	Width of the negative image selected by the operator

the lying behaviour detector cannot be applied straightforwardly for other cow behaviours because different samples of positive and negative images have to be defined and, as a consequence, the design of new procedures for the training and the testing phases is required.

Feeding and standing behaviours of dairy cows are also important as they are related to the comfort and physiological status of the cows (Bava et al., 2012; Cutullic, Delaby, Causeur, Michel, & Disenhaus, 2009; DeVries, Von Keyserlingk, Weary, & Beauchemin, 2003; Fregonesi, Veira, Von Keyserlingk, & Weary, 2007; Overton, Sischo, Temple, & Moore, 2002; Palmer, Law, & O'Connell, 2012; Provolo & Riva, 2009). In this study two further behaviour detectors were modelled and implemented in the previously developed CVBS. The aim was to assess the performances of the improved system for possible application regarding the automatic computation of two behavioural indices: the cow feeding index (CFI), which refers to the standing still position of the cows in the feeding alley with the head through the rack, defined as the ratio between the number of feeding cows and the total number of cows in the barn; and the cow standing index (CSI), which refers to the standing still position of the cows in the alley or inside the stall or to the ambulation, defined as the ratio between the number of standing cows and the total number of cows in the barn (Bava et al., 2012; Mattachini, Riva, & Provolo, 2011; Overton et al., 2002; Provolo & Riva, 2009).

2. Materials and methods

This section describes how the Viola–Jones algorithm was applied to model the classifiers of the cow feeding behaviour detector (CFBD) and the cow standing behaviour detector (CSBD). This description should allow the experiment to be repeated and reproduced in other similar free-stall barns. The characteristics of the barn, where this experiment was carried out, were those described in our previous studies (Porto, Arcidiacono, Anguzza, & Cascone, 2013; Porto, Arcidiacono, Giummarra, Anguzza, & Cascone, 2014).

The experiment was carried out in a study area within a barn that included a resting area consisting of 16 cubicles with sand beddings where 15 Friesian cows were housed. Cow milking occurred twice a day in the time intervals 5:30–6:30 and 17:30–18:30. Cows were fed ad libitum and feed was delivered in the early morning after the first milking but moved closer to the cows within the manger in the afternoon following second milking.

The multi-camera system was supported by other 6 cameras of the same model (Vivotek FD7131) used in the previous study in order to obtain a panoramic top-view image of the feeding alley (Fig. 1a). Image acquisition, calibration, rotation, and resizing were carried out on snapshots which were joined in order to obtain an output image of 415 × 1920 pixels that contained the plan view of the area of interest (Fig. 1b).

2.1. *The training phase*

The panoramic top-view images used to train the classifiers of the CFBD and CSBD were extracted from video-recordings acquired between the 1st and the 7th of August 2011, from 6:00 a.m. to 8:00 p.m. Images were selected by applying a 10-min scan sampling interval because previous studies have demonstrated that it was suitable for analysing standing and feeding behaviour (Endres, DeVries, Von Keyserlingk, & Weary, 2005; Mattachini et al., 2011). By applying this scan sampling interval, 84 panoramic top-view images were extracted each day for analysing standing behaviour and a total amount of 588 images was considered. For feeding behaviour, the image sampling considered only panoramic top-view images that showed cows feeding at the manger. These images regarded the 2 h after the first milking and 1 h after the second milking, when the feed which was delivered in the early morning was moved closer to the cows within the manger. Therefore, for such behaviour 18 panoramic top-view images were extracted each day from the video sequence.

The total number of stages of each classifier cascade that has to be constructed during the training phase (Viola & Jones, 2001, 2004) was established using the processes described for the cow lying behaviour detector (Porto, Arcidiacono, Anguzza, & Cascone, 2013).

2.1.1. *Cow feeding behaviour detector*

The training of the CFBD classifier required 656 positive images and 384 negative images (Fig. 2). The characteristics of the positive and negative images which were used to obtain the image samples are reported in Table 1. The number of positive images, which amounted to 656, was obtained by extracting the image sub-sets corresponding to all the rectangular areas of 227 × 102 pixels that showed a single cow at the feeding barrier in each panoramic top-view image. Likewise, the negative images were obtained by extracting areas