Validation of a commercial system for the continuous and automated monitoring of dairy cows activity

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Abstract

In order to improve animal welfare and enhance the comfort of dairy cows, the application of information technology (IT) within the intensive livestock farming takes a key role in a proper routine management.
This study aims to compare localisation and activity data provided by the CowView system, an automatic indoor localisation system for dairy cattle, with those obtained by a manual labelling procedure, twice within an observation period of minimum 25 hours per dataset.
Data from five selected dairy cows were represented by behaviours performed in relation to the occupied zones, and were classified in two categories: activity and localisation.
The identified activities performed by the dairy cows were standing, walking (both considered as being in the alley), resting (being in the cubicle) and feeding (being at the feeder). Indeed, the zone considered in the analysis were alley, in bed and feeding zone.
Data automatically and manually classified (used as a reference) were compared.
Among all the behaviours detected by the automated software, the most reliable results are those related to the activity of feeding (accuracy higher than 95%). The results showed that the CowView automatic monitoring system is able to identify activity zone classification (ALLEY, THROUGH, CUBICLES) with higher reliability compared to the specific activities performed by dairy cows. The results obtained support the CowView system as an innovative and effective solution for an easier management of dairy cows.

Keywords: behaviour, welfare, PLF, cow, herd monitoring

Introduction

Changes in the global demand of dairy products currently mean that the dairy industry is under pressure in increasing its productivity and efficiency (Gerber et al., 2011); moreover, the consolidation of farms has resulted in larger herd sizes (Von Keyserlingk et al., 2013), leading to difficulties for the farmer in identifying each individual cow and tracking its health and behaviour records.
Monitoring the behaviour of dairy cows is useful to assess their welfare, health status and comfort at farm level (Mattachini et al., 2013). Indeed as reported by Huhtala et al. (2007) it has been seen that changes in cows' behaviour are strong indicators for their health and welfare problems and therefore they can be used as input to an early warning system.

Knowing the position of the cows is substantially important to monitor their behavioural patterns and activity (Huhtala et al., 2007) obtaining also information about the time spent in the different locations of the shed. In fact, the time spent by the cows lying or feeding plays an important role in terms of milk production (Fregonesi et al., 2007; Mattachini et al., 2011); therefore, continuous observation of those behaviours is a tool for the farmer to monitor and control cows' health status and production.
However the continuous monitoring requires a lot of manpower/labour and it is time-consuming (Fontana et al., 2014), for this reason Precision Livestock Farming (PLF) can combine information technology into on-line automated tools that can be used to control, monitor and model the behaviour of animals and their biological response (Tullo et al., 2013).
Nowadays, the application of information technology (IT) within the intensive dairy farming takes a key role in a proper routine management in order to improve animal welfare and to enhance the comfort of dairy cows.
Indeed, several studies confirmed the feasibility of the use of IT achieving excellent results in the identification and localisations of the animals, feeding patterns recognition and oestrus detection (Porto et al., 2014).

The CowView system is an automatic indoor localisation system for dairy cattle providing positions and zone-related behavioural activities of tagged animals based on triangulation of very short radio-signals (Ultra Wide Band). The system is able to detect and monitor animal behavioural activities based on positioning, time at feeding table, time in bed, time standing and walking in the alley and distance travelled.
This study aims to compare localisation and activity data provided by the CowView system with those obtained by a manual labelling procedure. The manual labelling of the video was used as Gold Standard for the comparison, in order to check the accuracy of the system in localising zone occupied by the cows and their activity.
Therefore, data performed by five selected dairy cows were represented by behaviours in relation to the occupied zones, and were classified in two categories: activity and localisation.

Materials and methods

Data used for the comparison were divided in two datasets; the first one was used for the preliminary analysis of the output of the system, while the latter was obtained after the design optimisation of the CowView installation. The analysis consisted in the comparison between data collected automatically with the CowView system and the manual labelling performed on the video recordings obtained with a camera (Axis P5534 PTZ Dome Network, 30 fps, and 1280x720 pixel) placed in top down perspective under the roof of the barn.
Five selected cows (with a yellow letter on both flanks, and on the back of each cow) that were equipped with the CowView electronic tag were followed.
Data used for the comparisons were represented by the zone-related activities performed by the selected dairy cows, and were classified in two categories: activity and localisation (Table 1). In both datasets, the “feeding” behaviour was considered when the cow’s head was in the fodder line. “In bed” behaviour was considered when at least two legs were in the cubicle, but the system was not able to recognise if the cows were lying or not.

Table1. Classification of data used for the analysis according to the behaviours performed by the cows or their localisation.

Activity type	Localisation of the cow
Standing	Alley
Walking	Alley
In bed	Cubicles
Feeding	Through
At the drinker (only in the second dataset)	At the drinker (only in the second dataset)

First data set

Data collection consisted in around 38 hours of video recordings divided in 5 days. Since, one hour a day (5 days) for five marked cows were considered, the dataset for the validation analysis included only 25 hours (90,000 seconds - 2.7×10^6 frames) of recordings. During the manual labelling procedure, each activity/localisation was classified recording the type, the zone and the duration. The resulting dataset was merged with the output of the CowView system, in order to obtain the true positives/negatives and the false positives/negatives. Data from manually labelled videos were used as reference value (Gold Standard).

Second data set

The video data set covered around 42 hours of labelled video (150,405 seconds - around 4.5×10^6 frames) in 6 days. After the manual labelling, about 37 hours (132,053 seconds - around 3.9×10^6 frames) of activity and localisation data were available.
Also in this case, each activity/localisation was classified with the manual labelling procedure, recording the type, the zone and the duration.
Only in this dataset the categories "at the drinker" were added to the cow activity/localisation classification. This activity was not classified as "drinking" since the CowView system could not identify this behaviour precisely .
The resulting dataset was merged with the output of the CowView system, in order to obtain the true positives/negatives and the false positives/negatives. Data from manually labelled videos were used as reference values (Gold Standard).

The parameters evaluated for each activity/localisation were:

- ***Sensitivity***, parameter that tests the true positive rate:

$$\textbf{\textit{Sensitivity}} = \frac{\text{true positives}}{\text{true positive + false negative}}$$

- ***Specificity***, parameter that tests the true negative rate:

$$\textbf{\textit{Specificity}} = \frac{\text{true negatives}}{\text{true negative + false positives}}$$

Predictive value for a positive result (PV+), parameter that tests the probability that the CowView detects behaviour that cow is actually performing:

$$\textbf{\textit{PV+}} = \frac{\text{true positive}}{\text{true positive + false positive}}$$

Predictive value for a negative result (PV-): parameter that tests the probability that the CowView does not detect behaviour that cow is actually not performing:

$$\textbf{\textit{PV-}} = \frac{\text{true negatives}}{\text{true negatives + false negatives}}$$

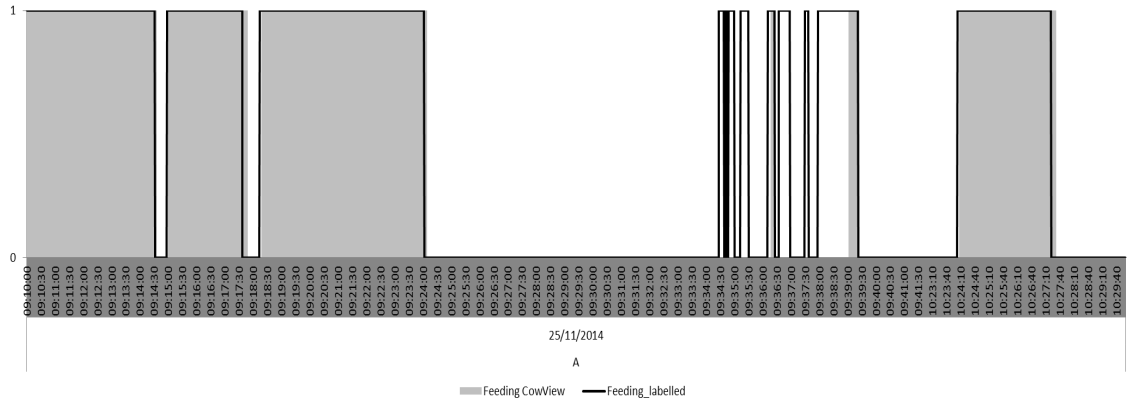
Accuracy: parameter that expresses the proportion of correctly classified behaviours among all events detected

$$\textit{Accuracy} = \frac{\text{true positive} + \text{true negative}}{\text{all events}}$$

Results and discussion

In Figure 1 an example of comparison between data manually labelled and automatically detected by the CowView system in relation to the activity of FEEDING is reported. Grey parts represent the amount of time (in seconds) spent by the selected cow in the activity of FEEDING detected by the CowView system. Black lines represent the actual time spent by that cow in the specific activity. Grey parts with the black frame represent the results obtained with the automated system that can be overlapped to the reference values (manual labelling). Black lines without grey filling represent a mismatch between the automated detection and the reference values.

Figure1. Example of comparison between data manually labelled and automatically detected by the CowView system in relation to the activity of FEEDING on a selected Cow (A) and on a selected day. Values of "1" indicate the activity detection (manual/automated)



In Tables 2 – 5 the results of the manual labelling and the continuous monitoring of the cow activity/localisation obtained with the CowView are reported for the first and the second dataset respectively. On the diagonal of the tables the acitivities/localisation that were detected both by the manual labelling and by the CowView System (true positive) are reported, while the rows represent the behaviours/localisation detected by the automated system that did not match with the reference values (manual labelling). All data are expressed in seconds. The last row is the total and actual amount of time spent by the five cows in a determinate activity/location, while the last column on the right represents the total amount of time that the cow spent in an activity /location according to the automated system.

Table 2. Results of the manual labelling and the continuous monitoring obtained on cow activity data with the CowView on the first dataset.

		Manually labelled				
		STANDING	WALKING	IN BED	FEEDING	Total
CowView	STANDING	11,851	171	686	323	13,031
	WALKING	2,300	2,322	671	2,488	7,781
	IN BED	17,542	137	22,870	76	40,625
	FEEDING	571	289	0	27,703	28,563
	Total	32,264	2,919	24,227	30,590	90,000

Table 3. Results of the manual labelling and the continuous monitoring obtained on cow localisation data with the CowView on the first dataset.

		Manually labelled			
		ALLEY	IN BED	FEEDING	Total
CowView	ALLEY	16,305	1,623	2,776	20,704
	IN BED	2,799	37,812	76	40,687
	FEEDING	871	0	27,738	28,609
	Total	19,975	39,435	30,590	90,000

Table 4. Results of the manual labelling and the continuous monitoring obtained on cow activity data with the CowView on the second dataset.

		Manually labelled					
		STANDING	WALKING	CUBICLES	THROUGH	AT THE DRINKER	Total
CowView	STANDING	13,125	237	1,014	798	947	16,121
	WALKING	3,075	4,801	243	697	267	9,083
	CUBICLES	889	214	44,336	0	1	45,440
	THROUGH	1,068	603	1,110	48,497	66	51,344
	AT THE DRINKER	2,687	316	0	0	7,062	10,065
	Total	20,844	6,171	46,703	49,992	8,343	132053

Table 5. Results of the manual labelling and the continuous monitoring obtained on cow localisation data with the CowView on the second dataset.

		Manually labelled				
		ALLEY	CUBICLES	THROUGH	AT THE DRINKER	
CowView	ALLEY	21,147	1,207	1,457	1,151	24,962
	CUBICLES	1,132	44,386	0	1	45,519
	THROUGH	1,682	1,110	48,535	66	51,393
	AT THE DRINKER	3,054	0	0	7,125	10,179
		27,015	46,703	49,992	8,343	132,053

In Figures 2-8 the comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the activity/location detected with the CowView system on the two data sets are displayed. After the design optimisation of the installation the five parameters considered (sensitivity, specificity, PV+, PV- and the accuracy) increased. In particular, the sensitivity for the STANDING activity and the specificity of the WALKING activity had nearly doubled.

In general, there was an increase of accuracy for all the activities/locations that reached values between 92 and 97 %.

The increase in sensitivity indicates an increase of the rate of true positives detected, meaning that the CowView system detected the same activity/location as the reference (manual labelling). The increase in specificity indicates an increase of the rate of true negative detected. In other words, the manual labelling and the CowView system can both detect if a behaviour is not occurring.

The increase in PV+ (Predictive value for a positive result) indicates the increased probability that the CowView detects a behaviour that the cow is actually performing. The increase in Predictive value for a negative result (PV-) indicates the increased probability that CowView does not detect behaviour that cow is actually not performing.

Figure2. Comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the activity of STANDING detected with the CowView system on the two data sets.

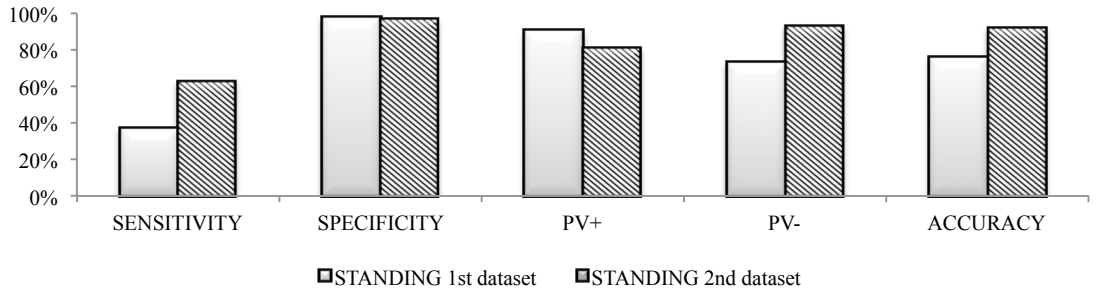


Figure3. Comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the activity WALKING detected with the CowView system on the two data sets.

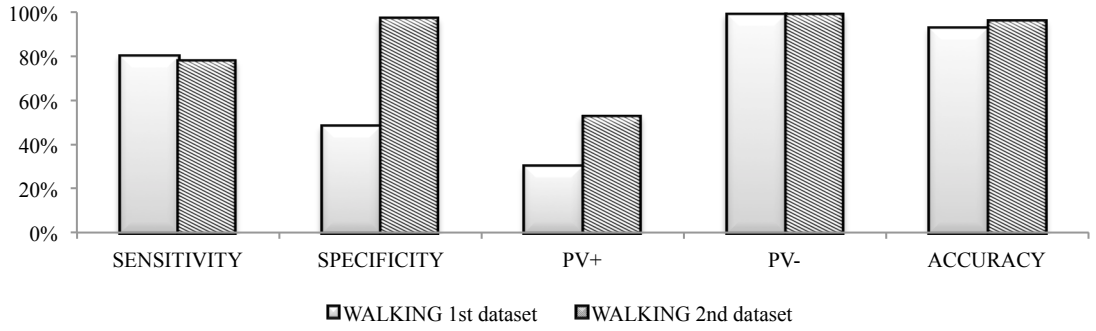


Figure4. Comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the activity IN BED detected with the CowView system on the two data sets.

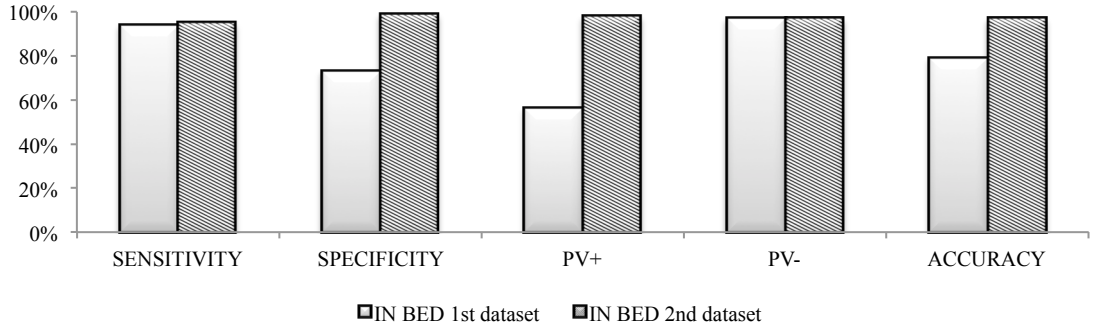


Figure5. Comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the activity FEEDING detected with the CowView system on the two data sets.

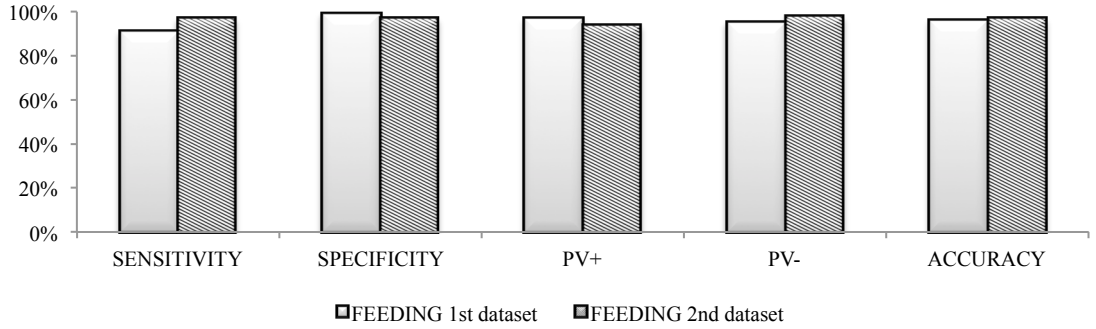


Figure6. Comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the location ALLEY detected with the CowView system on the two data sets.

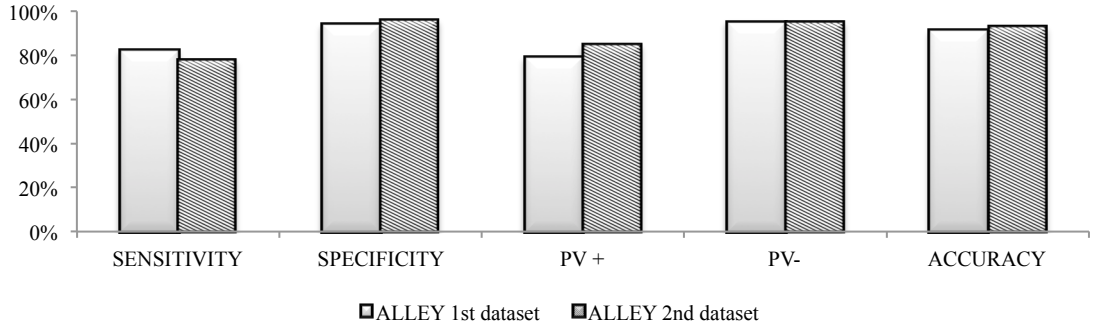


Figure7. Comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the location CUBICLES detected with the CowView system on the two data sets.

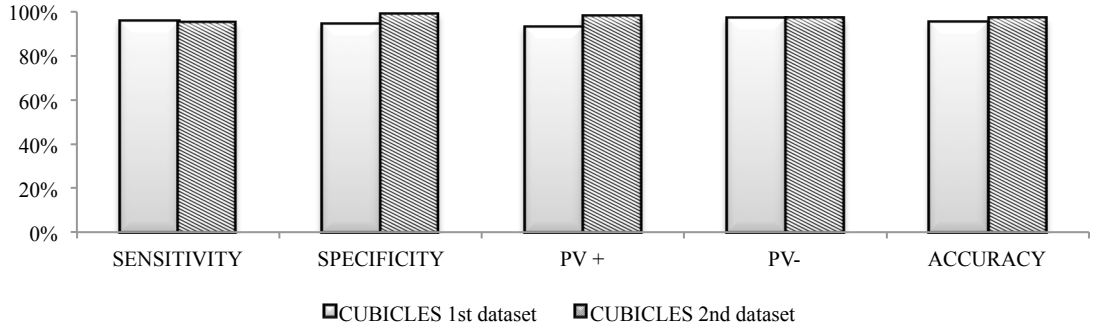
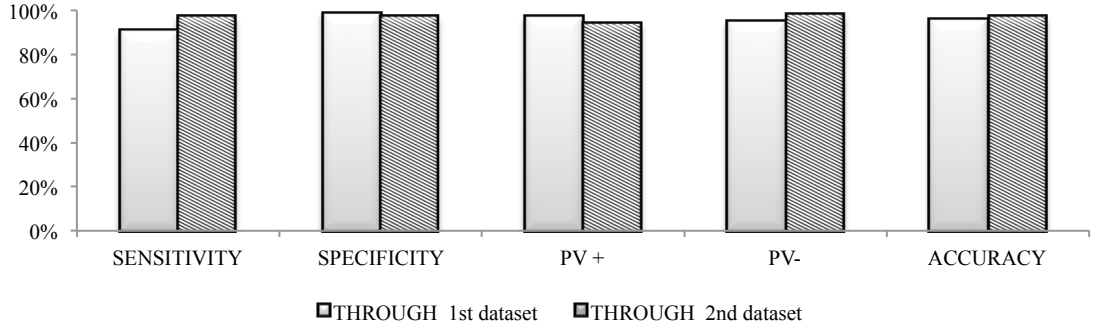


Figure8. Comparison between the sensitivity, specificity, PV+, PV- and the accuracy of the location THROUGH detected with the CowView system on the two data sets.



Conclusions

The results of this comparison study showed that the CowView automatic monitoring system is able to identify activity zone classification (ALLEY, THROUGH, CUBICLES) with higher reliability compared to the zone –related activities performed by dairy cows.
The preliminary results obtained are overall very encouraging even if the accuracy does not reach the 100%.
Anyway, the software is an innovative solution and an extremely valuable tool for the management of large herds of dairy cattle.
Further design optimisations of the CowView installation and relative validation will be necessary if the accuracy and the reliability of the system must be improved.

Acknowledgements

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