Oberschätzl, Rosemarie; Haidn, Bernhard; Harms, Jan; Peis, Rudolf; Stitzelberger, Isabella; Rose, Tobias and Bernhardt, Heinz

Automated recording of behaviour of dairy cows – a comparison of different technical approaches

Growing herd sizes increase the importance of supporting animal monitoring by automated data collection and analysis.Therefore the aim of the study was to compare and evaluate several technical approaches for data recording of individual animal as well as herd behaviour of dairy cows (by video technology, local positioning system, ALT-pedometers, rumination sensors, RFID) concerning to their quality, their performance and their handling. A basis for further studies of animal behaviour should be provided.
Concerning the selected technologies the analysis of the data collected by the local positioning system and the video technology came to similar results of herd behaviour. Regarding the behaviour of individual cows greater differences were detected in some areas because of signal shielding. The used ALT-pedometers and rumination sensors delivered additional information about behaviour patterns performed in certain areas assigned by the positioning system or the RFID.

Keywords
Dairy cows, animal behaviour, video technology, positioning system

Abstract
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With increasing herd sizes, an individual animal based monitoring of dairy cows becomes more difficult, so that whether only the herd as a whole can be watched or a higher workload for individual animal based controlling is necessary. This applies to farms, but also to scientific surveys, which often play a pioneering role for the development of new techniques or husbandry systems. So far, scientific data were mostly collected directly and/or by video surveillance. However, these two methods are very time consuming and are subject to strong subjectivity of the observing person [1; 2]. Therefore, in the context of „Precision Livestock Farming“, individual animal and automated data acquisition methods become more and more important for supporting the visual animal observation. Relating to different milking and cow traffic systems as well as activity measurements, electronic animal identification systems (RFID), pedometers, positioning systems and sensors for detecting feeding and rumination behaviour are already used in dairy barns [3; 4].

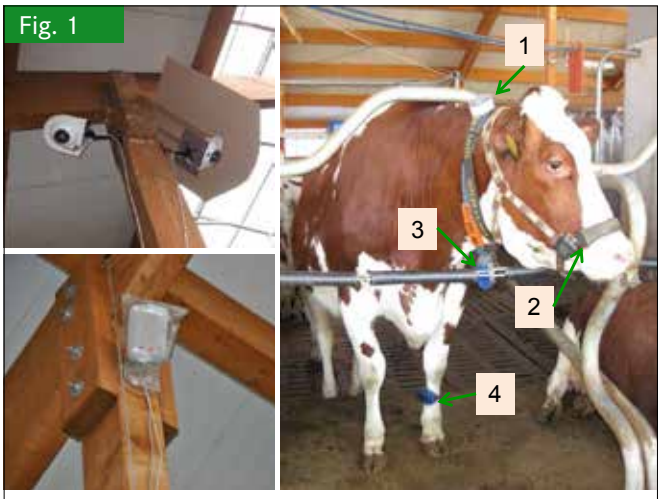
As a basis for further studies on animal behaviour and to optimize the trials, several technical approaches for data recording of individual animal as well as herd behaviour of dairy cows should be compared and evaluated in the present study concerning to their quality, performance and handling. The surveys were conducted of the Bavarian State Research Center for Agriculture in collaboration with the Technical University of Munich, the Universities of Applied Sciences Weihenstephan-Triesdorf and Kiel and the swiss Research station Agroscope Reckenholz Tänikon.

Materials and Methods

The studies were carried out on a farm in eastern Allgäu with 120 dairy cows in two performance groups, with two automatic milking systems, the cow-traffic procedure Feed-First and an automatic feeding system. In two experimental phases (Phase 1: 1.12.–21.12.2011; Phase 2: 6.2.–6.3.2012) various ethological parameters were assessed using the following technical approaches (**Figure 1**):

- Video technology (Mobotix D12 und D14; 6 cameras): rest and activity behaviour, nutritional behaviour, milking behaviour, area assignment
- Local positioning system (Ubisense Series 7000; 111 identification units, 14 sensors): rest and activity behaviour, nutritional behaviour, milking behaviour, area assignment

Fig. 1



Left: Video cameras and a sensor of the local positioning system which were installed in the free stall barn. Right: A cow fitted with an identification unit of the local positioning system (1), a rumination sensor (2), a transponder (RFID) (3) and an ALT-pedometer (4) (Photo: R. Oberschätzl)

- Rumination sensors (RumiWatch halters of the ITIN & Hoch GmbH, 6 cows of the low performance group): Feeding- and rumination behaviour
- ALT-pedometers (manufacturer company Holz, 15 focus cows in each performance group): rest and activity behaviour
- RFID technology of the AMS (DeLaval): milking behaviour, area assignment

Figure 2 gives an overview of the several functional areas in the barn and the installed data collection technique.

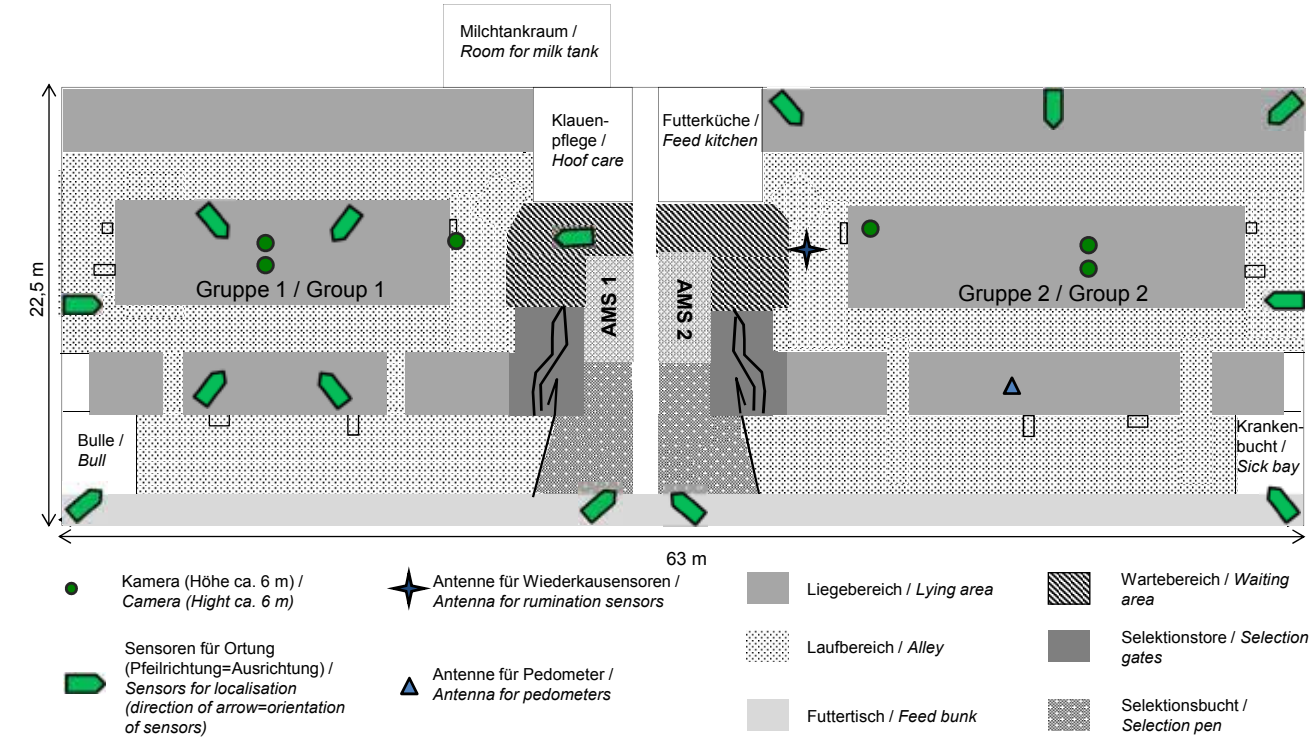
The digitization of the pictures of the video technology was conducted with the program Image J (Version IJ 1.45m, National Institutes of Health) according to the time-sampling method. A 5-min interval was chosen for the herd based analysis [2] and a 1-s interval for the analysis of individual animal behaviour. The data of the cows of the local positioning system, which were collected in a 1-s interval, were allocated to the defined functional areas, if these were assigned more than 5 s. All data obtained were stored in a PostgreSQL database and prepared for analysis.

When watching the herd, the comparison of the video technology (reference system) and the local positioning system was conducted in the low performance group on one day per phase. Due to limited capacity of the system, only 37 or 50 animals were equipped with an identification unit. This number was extrapolated on the whole number of animals in the group for each day of n = 60 and n = 65.

When watching the individual animal, the comparison of the video technology and the local positioning system based on the analysis of four focus cows on two selected days per trial phase.

For the evaluation of all techniques used for the individual animal detection, the residence assigned by the video technology, the local positioning system and the RFID technology, as well as the status detected by pedometers and rumination sensors were compared by synchronizing temporally.

Fig. 2



Design of the experimental barn and positioning of the data collection technique

Results and Discussion

The video technology as well as the local positioning system came to similar results regarding the herd behaviour. However, there were deviations in the several functional areas and day intervals. **Table 1** shows the whole number of deviations of herd shares, which were detected by the video technology and the local positioning system in the single functional areas and day intervals. It also presents the average absolute differences of the number of cows. Furthermore, the relative proportion of these differences regarding the maximum possible number of animals in the single functional areas is represented. The data of the proportions of negative and positive deviations are based on the total number of detected differences (n = 1556).

The herd shares, which were recorded by the video technology and the local positioning system, did not match exactly in 1556 of 1728 existing records (5-min interval). The absolute deviations in the areas were on average 1.4 to 3.3 animals. For example about 35 % of the deviations occurred in the lying area. This corresponds to an average deviance of about 3 cows and a proportion of only about 5 % relative to the maximum possible number of animals in the lying area. Because of a lower herd share detected by the local positioning system compared to the video technology, mainly positive deviations occurred in the lying area. The mostly negative deviations of the herd shares in the feeding area gathered by the local positioning system and the video technology can be explained by poor lighting conditions and image distortion of the video. Especially in the waiting area, fewer animals were determined by the local positioning system than by the video technology. Regarding the lower capacity of the waiting area (maximum 8 cows), the proportion of the deviant difference with an average of 20 % can be considered as high.

The results of the herd behaviour can be essentially confirmed by the individual-animal based comparison of the video technology and the local positioning system (n = 4 cows, n = 4 days). This showed that 57 % of the determined residences (e.g. single cubicle) of the focus cows coincided with both techniques. Similar to the results shown in **Table 1** one of the striking functional areas was the waiting area in front of the two AMS where an average deviance of more than 30 % was observed. The main reason for this is the considerably worse location accuracy in the waiting area due to signal shielding. This statement is confirmed by the fact, that in cubicles near the AMS also deviations in the order of about 30 % could be detected. In contrast, in other cubicles deviations on average between 0 and 10 % occurred [5].

The comparison of the approaches is exemplarily shown in **Figure 3** for demonstrating the possibilities and the limitations of the five techniques used for the detection of animal behaviour characteristics.

The qualitative comparison of the day courses of RumiWatch- and pedometer values as well as the area assignment by the local positioning system, the video technology (reference system) and the already in dairy farming used RFID technology reveal a matching sequence of resting and activity phases.

Table 1

Deviations of the obtained proportions of the number of cows in the functional areas detected by the local positioning system from those of the video technology over two days

Funktionsbereich *Functional area*	**Tagesintervall** *Day interval* h	**Abweichung der Ortung von Video[1]** *Deviation of the local positioning system from video technology[1]*				
		Anzahl aller Abweichungen[2] *number of deviations[2]*	**Ø abs. Anzahl[3]** *Ø abs. number[3]*	**Ø rel. Anteil[4]** *Ø rel. proportion[4]* %	**Anteil negative Werte** *proportion of negative values* %	**Anteil positive Werte** *proportion of positive values* %
Liegebereich *Lying area*	6 bis 18 / *6 to 18*	273	3,3	5,3	4,2	13,3
	18 bis 6 / *18 to 6*	264	2,5	4,0	7,0	10,0
Fressbereich *Feeding area*	6 bis 18 / *6 to 18*	267	2,8	4,5	14,3	2,9
	18 bis 6 / *18 to 6*	261	2,9	4,6	12,4	4,4
Warteraum *Waiting area*	6 bis 18 / *6 to 18*	225	1,8	22,5	2,0	15,1
	18 bis 6 / *18 to 6*	266	1,4	17,5	2,1	12,4
∑		1556			41,9	58,1

[1] Differenz der Anzahl Tiere in den Funktionsbereichen nach Video und Ortung./ *Difference of the number of animals in the different functional areas detected by video technology and the local positioning system.*
[2] Anzahl Datensätze mit unterschiedlichen Tierzahlen nach Video und Ortung./ *Number of data sets showing different numbers of animals detected by video technology and the local positioning system.*
[3] Durchschnittliche Differenz (absoluter Betrag) der Anzahl Tiere aller Datensätze ermittelt über Video und Ortung./*Average difference (absolute amount) of the number of animals identified by video technology and the local positioning system.*
[4] Relativer Anteil der durchschnittlichen Differenzen (absoluter Betrag) an den in den Funktionsbereichen maximal möglichen Tierzahlen
(Liege- und Fressbereich: n = Ø 62,5; Warteraum: n = 8)./*Relative proportion of the average differences (absolute amount) of the maximum capacity of cows in the functional areas (Lying area: n = Ø 62.5; Waiting area: n = 8).*

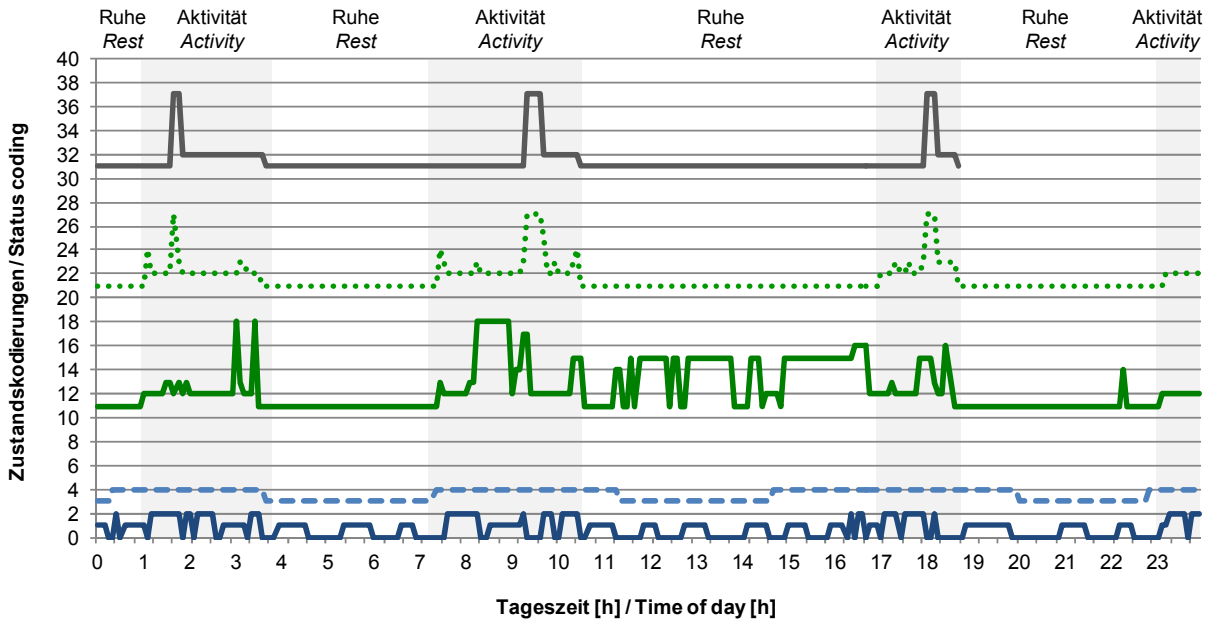
However, with the local positioning system considerable deviations were obtained due to signal interference near the selection and waiting area in front of the AMS. So the cow was alternately located in the cubicle (11), in the selection alley (15) and in the alley (14), while the other systems detected a continuous rest. The following activity phase (exchange of the animal in the feeding area) was determined by all methods, despite the RFID technology as a result of the lacking of RFID identification at the passage to the feeding area. Therefore, the cow was recognized again on its next visit at the selection gate.

Based on the present studies, the interference of the video material by poor lighting conditions (sunlight, darkness) as well as shield and distraction of positioning signals by stable equipment can be considered as main reasons for the deviations. The rumination sensors and their detection algorithm enabled – apart from problems in handling and their functional reliability – the recording of feeding and rumination behaviour of the considered cow in a way that is in accordance with the data collected by the other techniques. The ALT-pedometers also proved to be a functionally reliable technique for the detection of the rest and activity behaviour of individual cows. The study showed that for the evaluation of the different employed techniques several criteria should be considered depending on the objective of the investigation (**Table 2**).

Conclusions

Video technology is more suitable for online monitoring of the operations in the barn and can be seen as a reference system due to its high digitization effort. In contrast, local positioning systems and RFID technology allow an automated localization

Fig. 3



Wiederkausensor *Rumination sensor*	0: Andere Aktivität *Other activity*	1: Wiederkauen / *Rumination*	2: Fressen / *Feeding*
ALT-Pedometer *ALT-pedometer*	3: Liegen / *Lying*	4: Nicht Liegen / *Not lying*	
Ortungssystem *Local positioning system*	11: Liegebox / *Cubicle* 14: Laufbereich / *Alley* 17: Warteraum / *Waiting area*	12: Fressplatz / *Feed lot* 15: Selektionsgang *Selection alley* 18: Außenbereich Fressplatz *Outer space of feed lot*	13: Fressgang / *Feed alley* 16: Selektionsbucht *Selection pen*
Videotechnik (Referenz) *Video technology (reference)*	21: Liegebereich / *Lying area* 24: Laufbereich / *Alley* 27: Warteraum / *Waiting area*	22: Fressplatz / *Feed lot* 25: Selektionsgang *Selection alley*	23: Fressgang / Feed alley 26: Selektionsbucht *Selection pen*
RFID / *RFID*	31: Liegebereich *Lying area*	32: Fressbereich *Feeding area*	37: Warteraum *Waiting area*

Individual cow based comparison of techniques for automated detection of behaviour characteristics (cow of group 2, 18.12.2011)

Table 2

Evaluation of techniques used

Technik/*Technology* / Parameter/*Parameters*	Videotechnik *Video technology*	Ortungssystem *Local positioning system*	ALT-Pedometer *ALT-pedometer*	Wiederkausensoren *Rumination sensors*	RFID *RFID*
Handhabung/*Management*					
Handhabung und Funktionssicherheit *Handlig and functional stability*	++	+	++	-	+
Sicherheit der Bedienungsperson *Safety of the operater*	++	-	-	0	++
Zeitlicher Aufwand/*Time requirement*	- -	0	++	+	++
Aufzeichnungsqualität/*Recording quality*					
Beeinflussung durch Aufstallung *Influence of stable equipment*	+	-	++	++	++
Beeinflussung durch Lichtverhältnisse *Influence of lighting conditions*	-	++	++	++	++
Informationsgewinnung/*Information retrieval*					
Tierindividuell/*Individual animal based*	-	++	++	++	++
Herdenbasiert/*Herd based*	++	+	0	-	+
Automatisierungsgrad der Datenerfassung/ *Degree of automation of data collection*	-	++	++	++	++

++: äußerst positiv/*exceedingly positive*, +: positiv/*positive*, 0: neutral/*neutral*, -: negativ/*negative*, - -: äußerst negativ/*exceedingly negative*

of individual animals in the functional areas as well as the detection of herd behaviour. But stable equipment may affect the location determination by the local positioning system significantly. Therefore, a dense network of sensors is needed for allocating individual animals particularly in shielded and critical areas. Methods, such as the use of ALT-pedometers and rumination sensors provide additional information about the behaviour detected in the functional areas. It is crucial for the quality of the data to check the suitability and adjust the system settings of all the techniques used to the structural conditions before the experiment starts. A combination of the examined technical measurement methods allows a detailed and plausible detection of behavioral characteristics of dairy cows and represents an auspicious approach to animal control and to ensure animal welfare, both for research purposes as well as for practice.

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Authors

M.Sc. Rosemarie Oberschätzl is a research assistant in the research group „Husbandry of Cattle and Horses“, **Dr. agr. Bernhard Haidn** is coordinator for animal husbandry systems, **Dr. agr. Jan Harms** is head of the working group „Milk production and processing technology” and **Ing. agr. Rudolf Peis** is technical employee at the Institute for Agricultural Engineering and Animal husbandry of the Bavarian State Research Center for Agriculture, Prof.-Dürrwaechter-Platz 2, 85586 Poing-Grub, e-Mail: rosemarie.oberschaetzl@LfL.bayern.de

Ing. agr. Isabella Stitzelberger was a student in the degree program of agriculture at the University of Applied Sciences Weihenstephan-Triesdorf, Am Hofgarten 4, 85354 Freising-Weihenstephan,

M.Sc. Tobias Rose is a research assistant at the University of Applied Sciences of Kiel in the Department of Agriculture, Grüner Kamp 11, 24783 Osterrönfeld

Prof. Dr. agr. habil. Heinz Bernhardt is head of the Chair of Agricultural Systems Engineering at the Technical University of Munich-Weihenstephan, Am Staudengarten 2, 85354 Freising-Weihenstephan

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