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Validation of automated processed position data for assessing dairy cow behaviour

Rosemarie Oberschätzl, Bernhard Haidn, Rudolf Peis, Frederik Kulpi, Christoph Völkl

Indoor positioning systems are increasingly used in recording parameters of individual animal behaviour with dairy cows. This in turn requires finding ways of compressing the large amounts of data collected. Therefore the aim of the study was the evaluation of an already developed program for aggregating position data that, in particular, applies algorithms of cluster analysis. Video recordings of the feeding area within a freestall barn were used to validate the precision of the analytical methods and their suitability for evaluation of cow behaviour. Between both techniques, the recording of durations spent at each position by selected focus cows at the feeding area deviated mainly less than 10 seconds during the trial period. Through cluster analysis, the amount of position data could be reduced by a factor of 20. This made the recording of animal feeding behaviour easier. However, data aggregation always represents a compromise between practicability and loss of information, potentially leading to differing conclusions.

Keywords
Positioning system, cluster analysis, data aggregation, animal behaviour, dairy cows

Expanding herd size and increasing automation of work processes in dairy cow husbandry technology for automated animal monitoring becomes increasingly important. Different methods are already available for monitoring individual animals, such as video technology, pedometers and RFID as well as sensors for recording feeding and ruminating behaviour. Also increasingly developed and offered on the market for use in the investigation of animal behaviour are positioning systems (Harms and Wendl 2009, Stöcker and Veauthier 2013). However, the application of this technology means large amounts of data to analyse. For instance, for a 50-cow herd and a recording frequency of around one position per second, around 4.3 million data sets per day would be generated. For a practicable approach with this amount of data, selected methods of data compression and suitable processing routines are required.

Accordingly, at the Institute for Agricultural Engineering and Animal Husbandry of the Bavarian State Research Center for Agriculture in Grub (LfL) a program was developed for aggregating position data using mainly algorithms of cluster analysis. The aim of this study was to validate the precision of analysis processes with the help of video technology. Further, it was to ascertain whether the compression method is suitable for position data that has then to be evaluated.

Material and methods

As data basis, recordings of animal behaviour in a freestall barn at the Agricultural College in Triesdorf over a period of 7 weeks were used (phase 1: 26.11.–22.12.2012, phase 2: 16.1.–6.2.2013). There, the herd of around 70 cows was housed in a barn with free access to an automatic milking sys-

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tem. The barn was also equipped with an automatic feeding system. A "Real Time Location System" (RTLS) (Ubisense Series 7000, Ubisense, Düsseldorf) was applied for determining animal positions. Ten sensors were installed in the barn and 50 transponders were attached to the collars worn by the cows, for identification purposes. Communication between tags and sensors was via 6–8 GHz frequency radio signals. From time differences and angles of arrivals of the individual sensors, brought together into a network, the positions of the tags were determined via lateration and angulation. Four video cameras (Mobotix D12 and D14) mounted in the barn were used as reference system, both techniques were synchronised with a timeserver function. Figure 1 shows the layout of the freestall barn used in the study and positions of the installed equipment. Raw data from the recorded positions (time of recording, transponder number, x and y coordinates) were stored in a PostgreSQL database and subsequently further processed. Figure 2 shows the progression of the processing routines.

Firstly, the barn layout was presented in the vector format with zones for structured data processing then defined. These were interconnected accommodation areas (e.g. cubicles, feeding area). The zones were observed with a defined blurring of margins. Zones with the same use were brought together into single areas (e.g. lying area) – only the walkways were observed as a single entity. A method developed at the Institute for Agricultural Engineering and Animal Husbandry was mainly used for data aggregation. This method is based on multivariate cluster analysis with position data stored within a multidimensional array under the program language Python and processed according to the k-Means algorithm (Kulpi and Haidn 2014). Within the framework of the cluster analysis, data sets

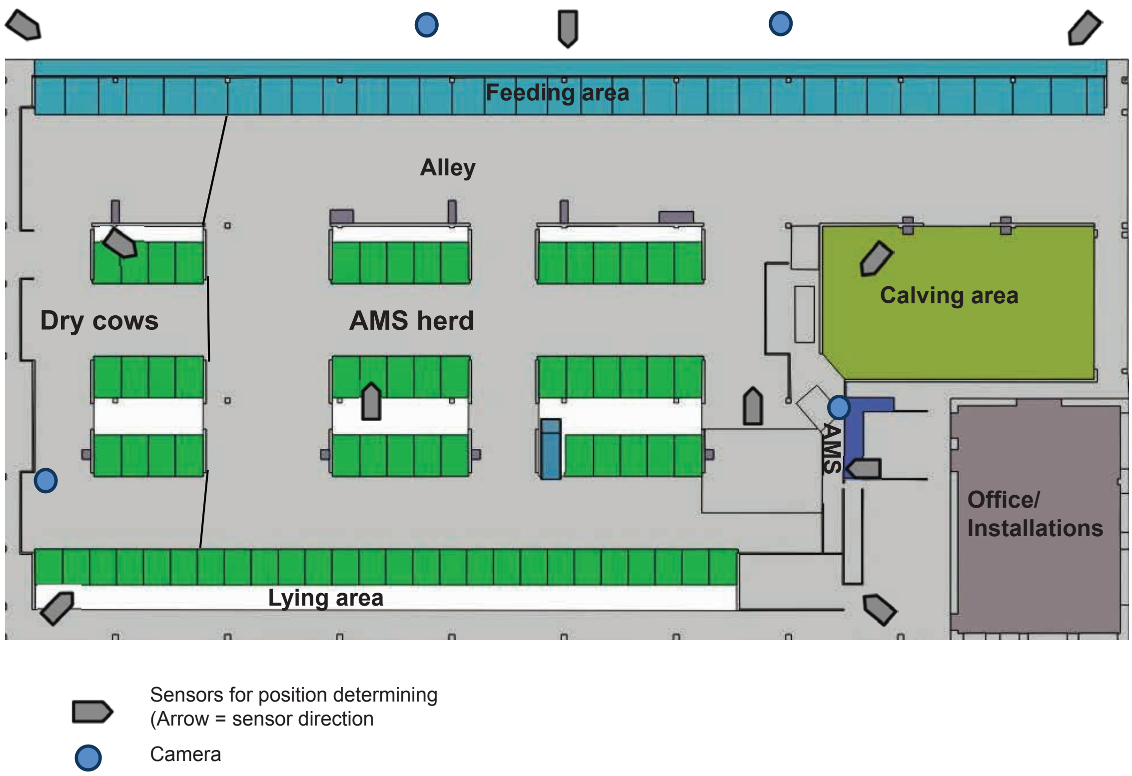

Figure 1: Layout of the freestall barn and positions of recording equipment

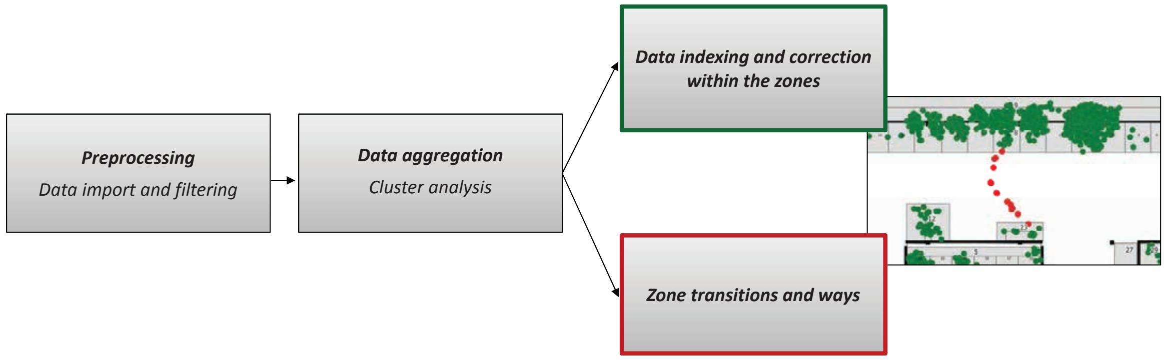

Figure 2: Program routines for processing and aggregation of position data, adjusted according to Kulpi and Haidn 2014

with similarities regarding position and time factors are assigned to a cluster. Start and end points are determined for individual clusters, the time related distances between which are taken account of in following aggregation. Decided upon the maximum time gap in this study was 10 seconds. Where the elapsed time was less than this, clusters that have already been formed were assimilated. Because of the greater amount of animal activity in the walkways, original data was applied for determining positions there. Conversely, aggregated data was applied in behavioural analysis within the previously defined zones. This enabled distance travelled to be determined, the results then brought together with the point coordinates (Kulpi and Haidn 2014).

Through clustering the established start and end points, as well as the recorded positions, it was possible to compare aggregated position data with video information. This comparison was limited to the feeding area in the barn. The position data were separately validated according to respective animals and days. Thereby, five focus cows were selected, the transponders of which delivered at least one single recording per second throughout the day over the five trial days. In the comparison given here, the starting time point represented the respective cow's entry at the feeding fence. The end point was defined as the departure of the cow from the feeding fence. In the video recordings, the starting point of each period was when the cow's forehead passed under the top rail of the feeding fence. The point of time when the respective cow entered or exited the feeding fence was stored and compared with the position data. Time differences between position data and video were calculated by subtracting starting time from end time points of the position data from those given by the video. A time difference between position and video data of ≤ 10 seconds was defined as agreeing (Völkl 2014). The differences in the time in the feeding area of focus cows as recorded by position data and video were tested for significance at a significance level of 0.05.

Results and discussion

Picture quality of the video recordings through the five trial days was occasionally unsatisfactory and so the time intervals from this source were not included in evaluations. This meant that a total 1,596 data sets were produced covering the presence of the five cows in the feeding area. In 71% of cases, the absolute time deviation between the compared recording systems was ≤ 10 s. Deviations of over 30 seconds occurred with a relative frequency of 9% (figure 3). The number of recorded feeding periods per day is generally influenced by the length of the selected critical interval. This means the resulting figure depends on the differentiation between shorter pauses within a feeding period and longer intervals dividing two feeding periods. As expected, increasing length of the critical interval reduced the number of daily feeding periods. In other studies, critical intervals of 20 min. (Metz 1975), or 49.1 min. (Tolkamp et al.2000) were defined. For recording the lengths of time between feeding periods, this trial selected a critical interval of 30 min. which, following a critical observation of the time period between the individual feeds via the video recordings, could be seen as plausible.

Per cow and day, an average of 5.7 feeding periods were detected (table 1). With the exception of cow 33010 (with average 3.4 feeding periods per day) the figures for the other cows lay in a similar range. A critical interval of 20 min. would lead, on average, to 6.0 feeding times. Because the video recordings were not continually available in sufficient quality, the position data were unable to be evaluated completely. In the time intervals where validating was possible, however, there were, with a significance level of 0.05, no significant differences recorded for position and video regarding presence of the focus cows in the feeding area. The position data registered an average 3.9 ± 0.9 h per cow and day and the video 4.0 ± 0.8 per cow and day.

Further focus cow feeding period figures that could not have been validated are displayed in table 1 from the clustered position data (average length of time of feeding period, average time between feeds, average daily feeding time). The times between the feeding periods measured over a day were unable to be taken account of because trial results were not always recorded on consecutive days.

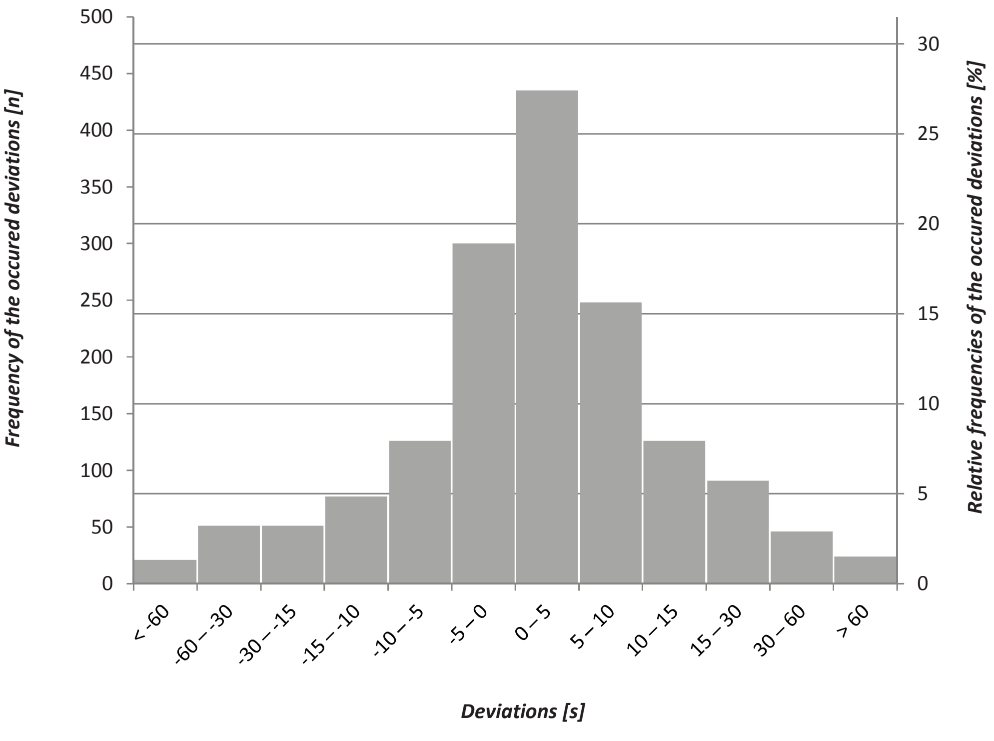

Figure 3: Absolute und relative frequency distribution of the time period deviations between the start and end points of presence in the feeding area, detected by video and positioning (n = 1596)

Table 1: Recorded information from position data, including standard deviation regarding feeding periods where times between feeds represent a critical interval of 30 min (n = 5 d, n = 5 cows) (Völkl 2014)

Cow	Ø number of feeding periods per day	Ø length of feeding period [min]	Ø time between each feeding period [h]	Ø daily feeding time [h]
28189	6,6 ± 1,1	56,8 ± 9,4	2,7 ± 0,3	4,7 ± 0,4
33010	3,4 ± 0,5	137,8 ± 24,7	4,6 ± 1,0	6,0 ± 1,0
33214	6,0 ± 0,7	64,5 ± 19,4	2,8 ± 0,3	3,4 ± 0,4
33239	6,0 ± 1,9	57,8 ± 28,5	2,7 ± 0,8	4,3 ± 0,3
37186	6,4 ± 1,1	71,0 ± 12,7	2,7 ± 0,6	5,3 ± 0,3
Ø	**5,7 ± 1,1**	**77,6 ± 18,9**	**3,1 ± 0,6**	**4,7 ± 0,5**

Because of the limited deviations with both recording methods with selected cows and days, it was shown that the developed procedure using cluster analysis represents a suitable method for aggregation of position data. The clustering and compressing reduced data sets by up to 95%. This, for instance, led in the case of one animal to a reduction from 105,440 data sets to 4,989 compressed data sets per day.

Recording length of related time spent in the feeding area with averaged coordinates and times of cow entry and exit from the feeding fence, enables a portrait of feeding behaviour throughout the day. However, through compression of the data it was no longer possible to see how often the cows changed their feeding place. This is because data aggregation only considered the time-related periods between the clustered information. For this reason, compression should consider time as well as coordinates (Metz 1975).

Conclusions

Cluster analysis is a suitable method for compressing large amounts of position data and enables data reduction of up to 95%. The reduced amount of data is easier to process and evaluate with regard to animal behaviour. However, eliminating original data can lead to loss of information (e.g. in case of feeding place change). In particular, for small areas of the barn, for instance where drinking or automatic brushing takes place, this can lead to false results regarding length of time and animal spends in such places. Thus, data compaction should not only take account of time but also of position. An as high as possible recording precision regarding positions in the barn through the positioning system establishes the basis of a reality-true positioning of the animal in the different areas of the barn.

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Authors

M. Sc. Rosemarie Oberschätzl is a member of the scientific staff within the working group "Cattle and Horse Husbandry", **Dr. agr. Bernhard Haidn** is work area coordinator for animal production systems, **Dipl. Ing. agr. (FH) Rudolf Peis** is member of the technical staff, and **Frederik Kulpi** was a member of the technical staff, 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

M. Sc. Christoph Völkl was a student of agricultural sciences at the University of Hohenheim, Garbenstraße 9, 70599 Stuttgart

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