Elaboration of Basic Methods for Automatic Analysis of Cows' Gait

V. Poikalainen[1], J. Praks[1], E. Kokin[1], A. Aland[1], I. Veermäe[1], S. Peets[1], J. Ahokas[2], M. Pastell[2], M. Hautala[2], D. Berckmans[3], C. Bahr[3], and D. Miljkovic[3]

[1]Estonian University of Life Sciences, 1 Kreutzwaldi Str., EE51014 Tartu, Estonia
e-mail: vaino.poikalainen@emu.ee
[2]University of Helsinki, Department of Agrotechnology, P.O. Box 28 (Koetilantie 3), 00014 Helsinki, Finland; e-mail: Jukka.ahokas@helsinki.fi
[3]Division Measure, Model & Manage Bioresponses (M3-BIORES), Katholike Universiteit Leuven, Kasteelpark Arenberg 30, B-3001 Leuven, Belgium
e-mail: Claudia.Bahr@biw.kuleuven.be

Abstract. Two different methods for automatic registration and analysis were used to produce data for comparison and analysis of lame and healthy animals' gait in Estonia.
A walk over mat with two quazi-piezoelectric sensors was elaborated and tested in co-operation with University of Helsinki. Preliminary analysis indicates that lameness can be seen as asymmetric gait and thus the quazi-piezoelectric walk-over mat is a promising tool for automatic leg problem detection.
A video-system was introduced to record walking pattern of cows in co-operation with Catholic University of Leuven. For video recordings three cameras were used to obtain top, side and leg views with StreamPix software video-signal capture. Possibilities of image based separation of dairy cows with real time vision system and preliminary settlement of this was developed. A model-based motion scoring system is proposed for derivation of image parameters needed for lameness detection.
About 600 cows once a week were investigated in a large dairy farm during four months' period. Dairy cows' gait pattern was recorded with the aid of quazi-piezoelectric walk-over mat and video-system. Preliminary lameness scoring was performed in the cowshed visually by two experts. These scoring results were later specified by expert commission on the basis of video-recordings. Lameness scores (according to Sprecher et al) were assigned as follows: 1–6,012 cases, 2–1,181 cases, 3–522 cases, 4–105 cases and 5–37 cases from total 10,653 cases. The database of cows' identification numbers, lameness scores and disordered legs description was created, that allows synchronization of walk-over mat signals data and video files.

Key words: dairy cattle, lameness, PLF, leg health, monitoring, welfare

INTRODUCTION

Lameness has been classified as the most important welfare problem in dairy cows (Anonymous, 2001). Farm Animal Welfare Council states (2009): 'Lameness is a major reason for premature culling of dairy cows, typically accounting for about 10% of culls. It causes considerable pain and distress to the cow, increases veterinary costs, takes much staff time, reduces milk yield and can also impair fertility. A recent UK study of mobility in 29,760 cows during 200 farm visits showed that the average prevalence of lameness was 17% though this varied greatly between seasons and farms, ranging from 1.4 to 49%'.

When lameness is detected in an early stage, the chances of a successful treatment and recovery are higher. Usually farmers and veterinarians detect lame cows by visual observation, scoring cows from 1 (sound) to 5 (severely lame) according to Sprecher et al (Sprecher et al., 1997). However, studies have shown that there are difficulties detecting animals in the early stages of lameness and mild cases of lameness are undiagnosed until they have progressed in severity. A cross-sectional study was conducted to estimate the prevalence of clinical lameness in high-producing Holstein cows housed in 50 free-stall barns in Minnesota during summer. The mean prevalence of clinical lameness was 24.6%, which was 3.1 times greater, on average, than the prevalence estimated by the herd managers on each farm. The prevalence of lameness in first-lactation cows was 12.8% and prevalence increased on average at a rate of 8 percentage units per lactation (Espejo et al., 2006).

Nowadays loose housing cowsheds with application of precision livestock farming (PLF) are becoming favoured in the whole world. However, as automation lessens contacts between human and animal to minimum, possibilities to discover individual animal's welfare and health problems in proper time decreases. With increasing number of cows the need for an objective, automated scoring which may enable earlier, more accurate detection of lameness grows (Berckmans, 2004, Poikalainen et al., 2004, Kokin et al., 2007).

Automatic detection of clinical symptoms of leg disorders in self-service units (milking robot, automatic concentrate feeder, etc.) – a four-balance system, where each of the legs is weighed – has been elaborated in cooperation of Finnish and Estonian researchers (Poikalainen et al., 2004; Pastell et al., 2005, 2006a, 2006b). Self-service technology, where such units are used, is effective primarily in middle size cowsheds (50-100 cows).

In large loose housing cowsheds the milking parlour and total mixed ratio are mostly used. The theoretical investigations of cows' gait patterns have been carried out in several countries, for example in Belgium (Maertens et al., 2007), USA (Carvalho et al., 2007) and others. There are three basic approaches for elaboration of automatic cows' gait registration and analyses – using of walk-through scales, systems with pressure sensitive walk-over mats and automatic video-imaging analyses.

Walk-through scales, based on vertical ground reaction force measurements of individual limbs were elaborated by Rajkondawar et al (Rajkondawar et al., 2001, 2006). The system consists of two parallel force plates with levelling platforms before and after the plates. Vertical forces measured over time for each plate can be used to calculate a number of limb movement variables. To separate the results of a group of animals walking through the system into multiple records of individual animals SoftSeparatorTM algorithm was developed. The system is now available commercially.

The preliminary investigations of using mats with sensors responding to the foot pressure have been carried out by different research groups (e.g. Maertens et al., 2007). At the University of Helsinki and Estonian University of Life Sciences a walk-over mat with two quazi-piezoelectric sensors was elaborated and tested for automatic cows' gait registration in free stall cowshed (Pastell et al, 2008).

Automatic use of video records for the assessment of cows' gait is studied in Belgium at Leuven Catholic University (Maertens et al., 2007, Poursaberi et al., 2009). Research has proved that vision techniques have great potential to be used for continuous quantification of lameness in cows. The results suggest that the automatic method by vision analysis is feasible to present the cows' real locomotion situations. The first results showed a positive linear relationship between cows' track ways overlap and locomotion scores by human visualization (Song et al., 2008).

There are no detailed comparative studies of different systems for automatic registration of cows' gait patterns yet. Also the problems of automatic cows' gait analysis combining different methods – particularly from the application possibilities point of view – have not been studied sufficiently.

MATERIALS AND METHODS

It is reasonable to build up the system for registration of gait as autonomous module. Such module must sustain to the hard environmental conditions in cowsheds and has to be suitable for future integration into general technological network. The system for inspection, identification and gait registration of dairy cows was installed in Estonia at loose housing cowshed according to this concept. Temporary monitoring station with two computers (one for video- and another for walk-over mat signals) was established close to the identification gate. Dairy cows' gait pattern was recorded simultaneously with the aid of quazi-piezoelectric walk-over mat and video-system (Fig. 1).

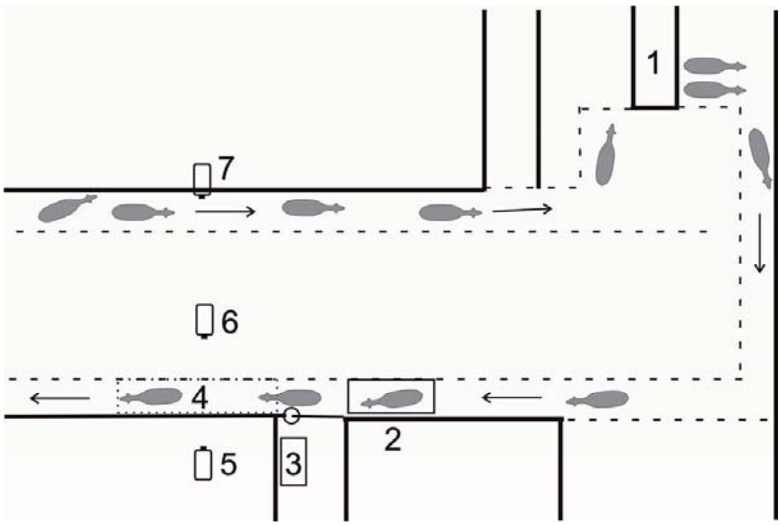

Fig. 1. The scheme of the experiment: 1 – milking parlour; 2 – identification gate; 3 – monitoring station; 4 – pressure-sensitive walk-over mat; 5-7 – video-cameras.

Quazi-piezoelectric walk-over mat

An electromechanical film Emfit (Emfit Ltd., Finland) was used as pressure sensitive element for the walk-over mat (Pastell et al., 2008). It is a thin, flexible, low-price electret element, which consists of cellular, biaxially oriented polypropylene film coated with metal electrodes, which can detect only dynamic forces (Paajanen et al., 2000). A force affecting the sensor causes a change in the film thickness resulting in change of the charge of the sensor that can be measured as voltage signal.

The sensors were placed sequentially and protected by sealing them between two 15 mm thick rubber carpets. The data was recorded at 200 Hz using USB-data acquisition unit (NI USB-6008, National Instruments, USA). The step force of each leg was identified from the measurement data (Pastell et al., 2008). The scheme of the automatic cows' gait registration system using walk-over mat with quazi-piezoelectric sensors and the placement of this in the cowshed are given on the Fig. 2 and 3.

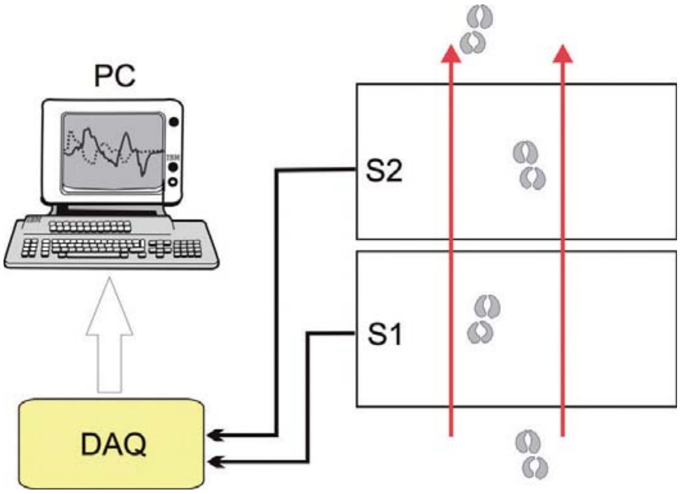

Fig. 2. The scheme of the automatic cows' gait registration system: PC – computer; DAQ – data acquisition unit; S1 – first sensor; S2 – second sensor; ↑- direction of cows' moving.

Fig. 3. Quazi-piezoelectric walk-over mat position in the alley.

Data was transferred into EXCEL format, cows' identification numbers were added and preliminary analysis was carried out. As a result the steps of cow's different legs were identified from video recordings and synchronized with signals of the walk-over mat. Of dynamic data acquired by measurements general and some specific numerical characteristics were calculated, including minimum and maximum peak values, number of peaks, time intervals between the peaks, steepness of slopes and integrated area of graphs.

Video-system

A video-system for cows' walking patterns recording was introduced in co-operation with Catholic University of Leuven. Three cameras were used to obtain top, side and leg views with StreamPix (NorPix Inc., Montreal, Canada) software video-signal capture (Figs. 4 and 5). All three cameras were GUPPY from ALLIED Vision Technologies with 1.4/3.5 mm lens, Pentax TV 1/1.8 4.8 mm lens and Theia C 1.3 mm NITTOH KOGAKO lens for hoof, side and top view cameras respectively. Examples of acquired images are given on Fig. 6.

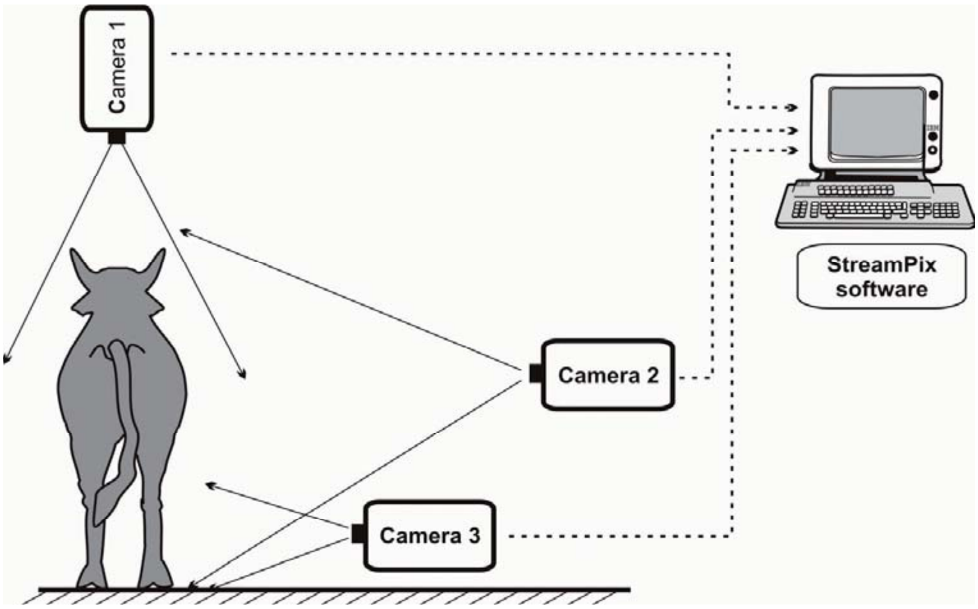

Fig. 4. The scheme of the video-cameras' position in the cowshed.

Fig. 5. Installation of video-system in the cowshed: 1 – top camera; 2 – side camera; 3 – hoof camera; 4 – calibration mat.

Fig. 6. Hoof, side and top camera images.

Videos of identified cows from different cameras are analyzed with specific software in Leuven. A model based motion scoring system is used for derivation of image parameters needed for lameness detection (Pluk et al, 2009).

Lameness scoring and the formation of database

About 600 cows once a week were investigated during four months' period. The cow' gait was registered with walk-over mat and video-system described above. Visual evaluation of the lameness score and lame leg was carried out at the same time. Lameness score was detected by visual observation, scoring cows from 1 (sound) to 5 (severely lame) according to Sprecher et al (Sprecher et al., 1997). Preliminary scoring was performed in the cowshed by two experts, later scoring results were specified by expert commission on the basis of video-recordings. Video and Excel files were encoded as follows: cow's number_lamenesss score and disordered leg_date_time (Fig. 7).

Fig. 7. Encoded video-recording.

The EXCEL database consisting of cows' identification numbers, lameness scores, disordered legs description and some other cows' data was created that allows synchronization of walk-over mat signals data and video files.

RESULTS AND DISCUSSION

During the experiment 10,970 cows' gait patterns were recorded, from which 10,653 cows were identified. Lameness scores were assigned as follows: 1–6,012 (76.5%) cases, 2–1,181 (15.0%) cases, 3–522 (6.6%) cases, 4–105 (1.4%) cases and 5–37 (0.5%) cases from total 7,857 scores assigned. Lameness score was not assigned when cows moved too quickly or too close to each other (2,796 cases).

As the cows walk in a row one after the other, it is essential that their movement speed should be moderate and with regular pattern. Otherwise it is difficult to get usable information about individual cow's gait (Fig. 8). Standstill, slipping, crush, flowing etc complicates interpretation of sensors' signals from the walk-over mat.

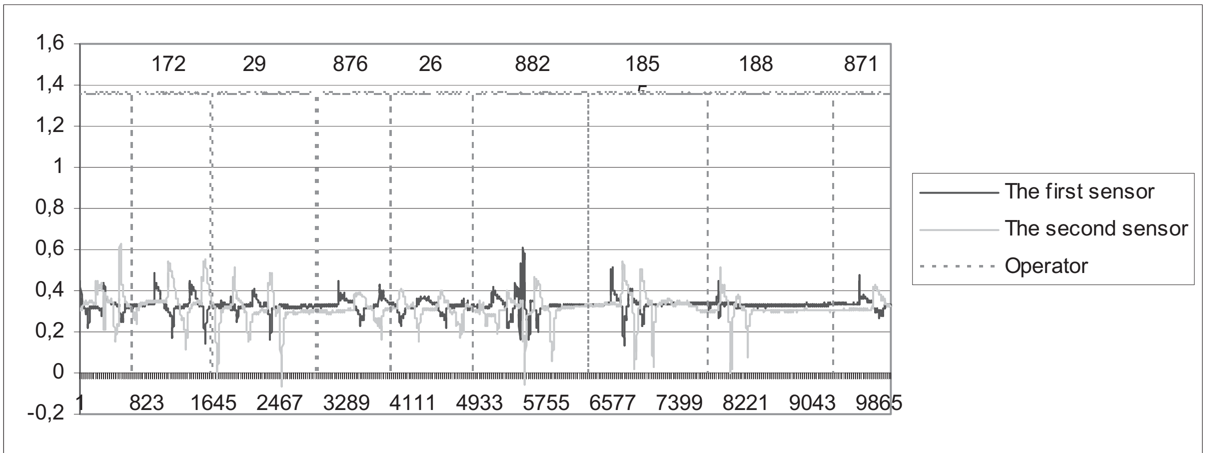

Fig. 8. Walk-over mat data. Individual cows' data (identification number in the top line) are separated by operator's signals.

It is possible to distinguish visually between healthy and lame cows when they pass the walk-over mat in moderate tempo (Fig. 9). More regular pattern indicates healthy cows' gait, certain irregularity and additional slopes indicate lame cows' qait. Analysis of the measurement data showed that healthy cows gait curves had lower number of peaks (5-7 positive and 4 negative peaks versus up to 13 positive and 6-7 negative peaks), the number of turning points was accordingly 12-13 versus 18-23 and the first peak was substantially higher than the second one. The distance between peaks also depends on the cow's lameness. All these informative parameters of the walk-over mat output curve should be used as inputs for lameness detection algorithms, based on stochastic analysis (neural network, fuzzy logic etc). Therefore the elaboration of lameness detection algorithms and their comparison will be the next and most complicated step of the investigation.

However, even though there are clear indications that the signals of healthy and sick cows are different, there are some complications to be solved (Pastell et al, 2008). It has turned out that the variability of signals for both sound and lame cows makes automatic detection unexpectedly difficult. In the same time, measuring the gait daily helps to quantify the amount of natural variation in the gait of different cows and to deal with the data more appropriately. To simplify the use of the models it is reasonable to apply separation of some measurement results before processing.

Output signals of the walk-over mat are also influenced by cows' behaviour. For example these signals do not indicate to which leg (left or right side) belongs the first peak of the curve. A successful measurement requires that both, the fore limb and hind limb, have hit the sensor in a proper manner. A significant portion of the measurements did not fulfil these requirements due to the unpredictable and anxious behaviour of the cows. These problems could be solved by special measures which influence the step behaviour of cows accordingly (the proper leg hits the proper sensor). Specific experiments are needed for that.

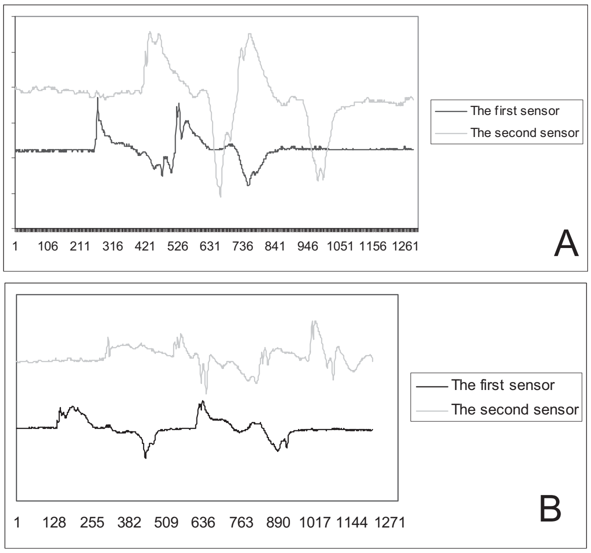

Fig. 9. Healthy (A) and lame (B, lameness score 3) cow's gait patterns.

Gait analyses using video-recordings is also quite complicated, especially when cows pass the recording zone in a row. In this case an automatic separation of cows in a sequence is necessary to get information about gait features from individual cow. Possibilities of image-based separation of dairy cows with real time vision system were analyzed and preliminary technical solutions were developed in the Catholic University of Leuven (Poursaberi et al, 2009). An algorithm for cow separation was proposed based on local image filtering and statistical analysis of binary images frame by frame. The proposed algorithm is under improvement to cope with extra overlap (more than two cows), variant background light conditioning, missing parts of reconstructed binary image from cow (sometimes some parts of body is similar to the background and in reconstruction we miss these parts). Gait analyses of this experiment by video-recordings are described in Pluk et al (Pluk et al, 2009).

These two methods (use of walk-over mat and video-recording) can be compared and if useful, combined for more reliable results.

CONCLUSIONS

The number of lame cows' scoring in the heard under observation was large (23.5%). From these cases significant to severe score was in 8.5% of cases.

From the tests conducted we may conclude that automatic detection of lameness by means of quasi-piezoelectric walk-over mat and by video images analysis is possible.

From the output signal of quasi-piezoelectric walk-over mat some informative parameters (number of peaks in the gate curve, distance between peaks, number of turning points, relative height of the subsequent peaks) can be used in algorithms for automatic detection of lameness.

Disturbing influence of certain behavioral pattern and crowding of cows can be eliminated by automatic separation of cow's data. Some technical means to influence cow's step behavior can be used for leg signal determination.

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