Experimental setup for the study of a computer vision based automatic lameness detection system for dairy cows

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Abstract

The objective of this study is to develop an automatic detection system to quantify the severity of lameness for dairy cows, based on both analysis of video recordings of the cow‘s gait and with her associated behaviour. This paper describes the need for this type of research, and will discuss the experimental setup. During three recording sessions, 92.5% of the animals in the herd were recorded while walking through the video-corridor with at least two full gait cycles. This result indicates that the chosen setup, consisting of a corridor from the milking area, which the cows enter one by one through a separation gate, and two video cameras in two different angles, can be a useful tool for gait analysis.

Keywords: dairy cattle, gait, lameness, automatic detection, computer vision

Introduction

In modern European dairy farming, there is a trend for a decreasing number of dairy farmers, but on the same time the herd sizes become bigger (Eurostat, 2011). Bigger herds imply that the farmer spends less time to each individual cow to monitor its health and productive status. Automation and new technologies in the feeding and milking process help the farmer to solve this problem. A logical next step would be to automate the monitoring of the animals. As known, intensive farming systems sometimes have side effects, especially concerning the welfare of the animals. Lameness is such a side effect, and it is a major concern in modern dairy farming. It is rated as the second largest problem in intensive dairy farming, after mastitis (Kossaibati *et al.*, 1997). The prevalence of lameness ranges from 5% to 70%, depending on several farm conditions (Clarkson *et al.*, 1996; Barker *et al.*, 2010; Tadich *et al.*, 2010). This prevalence might even be an underestimation due to the low awareness, difficult recognition and the poor registration of lameness cases (Whay, 2002; Leach *et al.*, 2010a). Under conditions of robotic milking, painful lameness impairs with visits to the milking station and reduces milking frequency (Borderas *et al.*, 2008). Additionally, the issue is part of the intensified welfare societal discussions (Whay *et al.*, 1998; Leach *et al.*, 2010b). The economic impact of lameness is significant for the farmer, because losses increase with severity

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and the type of lameness (Kossaibati & Esslemont, 1997; Wilshire & Bell, 2009; Bruijnis *et al.*, 2010). These losses comprise the treatment costs, the indirect losses of decreased milk yield, reduced fertility, higher replacement rates and a lower selling price of the culled lame animal (Ettema & Ostergaard, 2006; Bruijnis *et al.*, 2010).

Lameness is often visually scored by a trained person in order to rate the lameness incidence on the farm (Clarkson *et al.*, 1996; Barker *et al.*, 2010; Borderas *et al.*, 2008). There are several scoring methods available (Sprecher *et al.*, 1997; Amory *et al.*, 2006; Tuyttens *et al.*, 2009). The most used method is the 5-point lameness scale developed by Sprecher *et al.* (1997). However, the assumption is that lameness scoring in practical situations is hardly done (Whay, 2002). When done, it is not frequently enough and uniformity in scoring methods will not be present (Brenninkmeyer *et al.*, 2007; Thomsen *et al.*, 2008; Van Nuffel *et al.*, 2009). This was the main reason for several researchers to start the development of automatic scoring methods.

Automation of lameness detection in dairy cattle is a hot topic in agricultural science. Many solutions are documented, and some of them even on the market. One method for automatically detecting lameness is based on strain gauges (Pastell *et al.*, 2006; Pastell *et al.*, 2008a) or force sensors (Kujala *et al.*, 2008; Pastell *et al.*, 2008b) to measure the weight load in each leg. This system can detect lameness very well, but the installation of the system is costly. Another disadvantage is the importance of the hoof placement on the scale. Misplaced hoofs lead to unsuccessful measurements.

Another promising technique to detect lameness is based on the lying behaviour of the animal (Chapinal *et al.*, 2009; Ito *et al.*, 2010). High lying times, long lying bouts and variability in the duration of the lying bouts could be associated with severely lame animals. This technique was only able to detect lameness in a later stage, when the cow was suffering from it (Whay *et al.*, 1998). Our research is about detecting lameness in any stage. Detecting lameness in an early stage is preferable, so that treatment can be started on time before the cow starts suffering, and as useful as being able to follow the course of lameness over time.

Previous studies that mimic the farmer‘s observations were the logical next step. These studies used vision techniques to detect lameness and showed some promising results (Song *et al.*, 2008; Pluk *et al.*, 2010; Poursaberi *et al.*, 2010). The results in the study of Song *et al.* (2008) showed a correlation coefficient of 94.8% between the human observed hoof locations and the image processed hoof locations in the frame.. This suggested the feasibility of vision analysis as a method to present the cows' locomotion. Pluk *et al.* (2010) found a relation between the step overlap and the manual five-point gait scores of Sprecher *et al.* (1997). This indicates the possible use of the step overlap variable as an automatic lameness detection tool. However, Pluk *et al.* (2010) stress that this variable is not strong enough to use it as a single classifier for lameness. The study of Poursaberi *et al.* (2010) went a step further. They filtered the body of the cow out of the image, and used the curvature of the back arch as a lameness indicator. The results were very promising. The next step will be to combine the findings of these studies in a new experiment. Therefore, in this paper, the experimental setup for the next step in this process is made. The objective of this research will be to combine gait parameters that can be visually detected from the image, and incorporate them all together in a robust lameness detection tool. In this research we would like to elaborate on the practicability and robustness by also looking at different cows (genetics) held in different circumstances (climate, housing, feeding).

Some remarks should be considered when using vision technology to detect lameness. The domesticated dairy cattle are descendants from ranging wild cattle that were prone to predator

attack. In order to improve their chance on survival, they masked any signs of pain and its implied weakness (Phillips, 2002). This can imply that cows will only show their pain when their level of pain is high and their suffering unbearable. This might be a drawback in the early detection of lameness based on visual information as only a severely lame cow will show pain by an uneven or changed gait. It is also possible that cows hide their weakness from other herd mates in order not to lose their rank in the social hierarchy of the herd. A lower rank implies less eating, less lying and more standing, which in turn leads to an increased chance on lameness (Galindo & Broom, 2000; Galindo *et al.*, 2000; Galindo & Broom, 2002).
In order to develop an automatic detection system to quantify the severity of lameness for dairy cows, based on both the analysis of video recordings of the cow‘s gait and the behaviour of the animal, this paper will determine the feasibility of the experimental setup of this project.

Material and Methods

Animals and housing

The study comprised 70 lactating Holstein cows on a commercial dairy farm. The average milk production on the farm in 2009 was 12500 kg/year/cow. The cows were housed in a fully roofed free stall open cowshed without cubicles and dry manure floor. The cows were milked in an adjacent concrete-floor parlour equipped with two milking robots. The minimal time between two milking sessions was set at 4 hours, and if the cows did not come by themselves in 8 hours, they were fetched from the herd. The cows were fed concentrates according to their milk production in a concentrate feeding station, and in the milking parlour. The maximal amount of allocated concentrates was 10.0 kg/day. Twice a day, a TMR was supplied by a local cooperation.

Sensors

Cow gait was recorded from two perspectives: one in side view, and one in top view. The camera in side view was an AVT IEEE1394 Guppy F080C colour camera (Allied Vision Technologies GmbH, Stadtroda, Germany) with a resolution of 1024x768 pixels in RGB colour format, at a frame rate of 30 fps. The camera in top view was an AVT IEEE1394 Guppy F036C colour camera (Allied Vision Technologies GmbH, Stadtroda, Germany) with a resolution of 800x640 pixels in RGB colour format, at a frame rate of 30 fps. The images were taken in a concrete-floor corridor when the cows left the milking area. A separation gate made the cows enter the corridor one by one. The actual recording started after a time delay when the gate opened to let the animal pass, and stopped after a predefined time period of 15 seconds.
The cameras were connected to the operating computer by IEEE1394-FireWire cables. In order to cover the 30 meter distance between cameras and computer, 6 port FireWire Repeater Boxes were used. The hubs were connected to a 12 VDC power net in order to operate at the maximal transfer speed of 400 megabits per second (Mbps).
Visits to the milking station and feeding stations, and gate passes were recorded by the management software.

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Scoring

The quality of the recorded videos was determined on the walking behaviour of the cow (Table 1). Each recording was manually labelled by one of the four categories in Table 1.

Table 1. Evaluation of video usability based on animal walking behaviour

Video score	Resulting Behaviour
Category 1	No video records available of the animal
Category 2	Cow stops walking, and keeps standing still. Less than 2 steps are taken before/after stop
Category 3	Cow stops walking or slows down. More than 2 steps are taken before/after stop
Category 4	Cow walks at steady pace the entire length of the path

Database building

Data included in this study was collected twice a week on the farm. Gate passing of the cow was registered by the management software by date, time and cowID. The recorded videos received a date- and time stamp, so the video file could be linked to a gate passing event in order to get the cow identification, and a video usability categorisation. All the data were stored on an 8Tb Western Digital ShareSpace storage unit (Western Digital, Lake Forest, USA).

Results

The experimental setup makes it possible to make video recordings of walking cows when they leave the milking area. The video in side view position is recorded with a resolution of 1024x768 pixels, and the top view videos have a resolution of 800x640 pixels. In order to reduce the file size and discard the recording of unnecessary data, a region of interest is selected. Only the region in the picture where the cow is walking is saved to the disk. This allows us to save up to 2/3rd of disk space. The quality of the picture was checked. A snapshot of such a video in side view position can be seen in Figure 8. A top view snapshot can be seen in Figure 9. In further research, gait characteristics will be calculated from these video-frames.

Figure 1. Side view snapshot from a recorded video

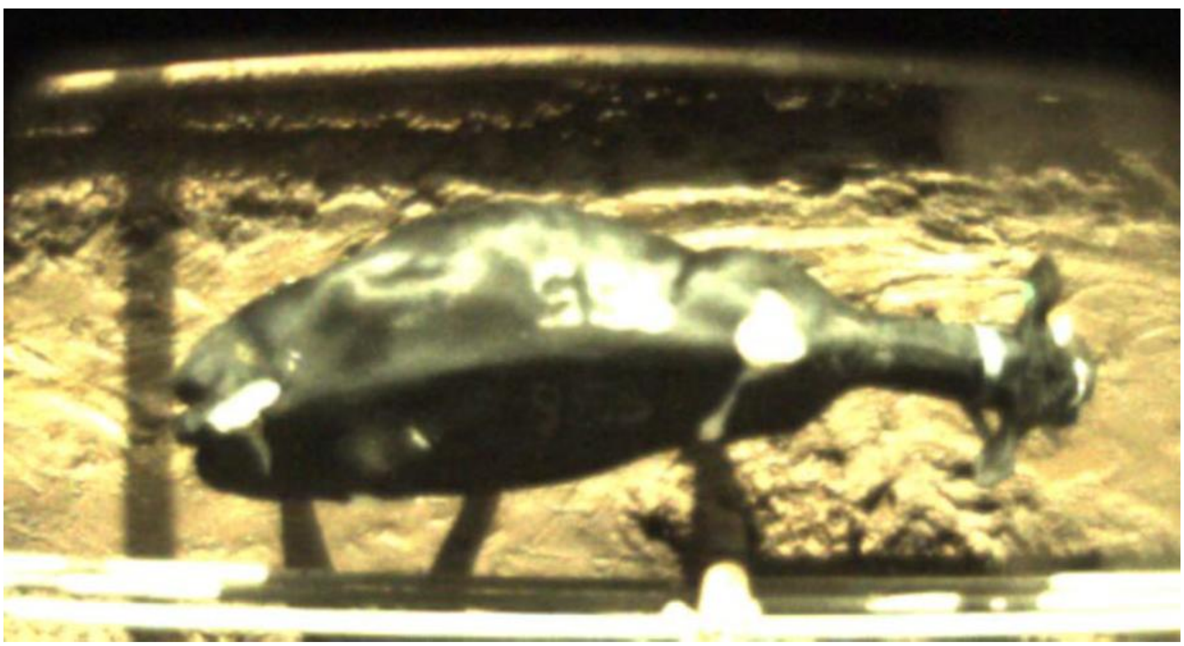

Figure 2. Top view snapshot from a recorded video

The objective of this study was to have at least 1 recording of each cow per session. In a two week period, three recording sessions were executed. The first was 6 hours and 15 minutes long, the second was 9 hours 30 minutes long and the last one was 6 hours and 45 minutes long. A total sum of 22 hours and 30 minutes was covered with recordings. The first two sessions started around 07.15 AM local time, and the third one around 09.00 AM.
The results are summarized in Table . The results of the sessions are expressed in absolute values (column 2, 4, 6 and 8) and in relative values (column 3, 5, 7 and 9). The 'Total' column is not a new session, but presents the animals that were in all three sessions. The session total

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of the column 'Total' (67) is smaller than the session total of the other three sessions (70, 70 and 71, resp.) due to the exclusion of seven dried off animals and the inclusion of three calved animals in the time between the two last sessions. 67 animals attended all three sessions (last two columns), three cows attended two sessions, and four cows attended only one session. The column 'Total' shows that one cow was not recorded in either one of the three sessions. 50 cows (74.6%) were recorded in at least one of the three sessions in which they walked the full length of the path. Ten (14.9%) cows were categorised in category 4 in all three sessions. The recordings of 30 (42.9%) cows were labelled with category 4 in at least two sessions.

Table 2. Results of the video usability scoring for three sessions (#: number of animals)

	Session 1		Session 2		Session 3		Total	
	#	%	#	%	#	%	#	%
Category 1: standing	28	40.0	7	10.0	18	25.4	1	1.5
Category 2: walking <2 steps	7	10.0	11	15.7	11	15.5	4	6.0
Category 3: walking >2 steps	9	12.9	15	21.4	13	18.3	12	17.9
Category 4: walking full path	26	37.1	37	52.9	29	40.8	50	74.6
Session total	70	100	70	100	71	100	67	100

Discussion

The results in this study show that 74.6% of the cows were categorised in category 4. These recordings are the most interesting to analyse gait characteristics. The animals are walking at a steady pace along the path. Walking the path takes 4 or 5 gait cycles, so 4 to 5 subsequent strides can be analyzed. If the videos of Category 3 are included, a total sum of 62 cows (92.5%) can be reached. The cows in those videos do not walk at a steady pace, but more than 2 steps are recorded. Images of standing animals can be found in the videos of Category 2. Here, gait characteristics cannot be identified, but there may be some standing characteristics that can be linked to lameness. After three recording sessions, one out of 67 cows (1.5%) was not spotted in any of the recordings, meaning that she did not leave the milking area while the recordings took place, or that her recording was totally useless.

Useless recordings can have different underlying reasons. First of all, some cows kept standing when the selection gate opened. However the cow was not moving, the recording started after a short time delay. This caused the system to save files where no information could be found in. This could be resolved by including a light sensor that detects if the cow really passed the gate before starting the recording. Secondly, some cows walked through the selection gate, but stopped walking before they reached the part of the walking path that was filmed. Another event that made a recording useless was that some cows turned 90 degrees or more in the walking path when they saw something new in the feeding trough.

The behaviour of the animal is quite repetitive. In our recordings, we found out that ten cows on a total of 67 animals with three recordings (14.9%) were labelled in all three sessions with a recording of Category 4. The recordings of 30 cows on a total of 70 animals with at least two recordings (42.9%) were labelled in category 4. The walking behaviour of the animal is defined by the nature of the animal. Some cows just like to take their time before setting the next step. Especially lame animals or animals that suffer from walking will rather rest between their steps than walking at a steady pace, the so-called *willingness to walk* (Whay, 2002). This is a challenge in the current setup, because the animals are free (of will) to walk in the walking path. The chance that lame animals will walk the whole length of the path is rather low. On the other hand, the objective of the study is to detect lameness in an early stage, before the pain becomes unbearable.

The recording periods had to be interrupted because of the darkness. When darkness came up, there was not enough sunlight left to see the cows walking. This can be improved by installing some artificial lights. It will make it possible to make recordings at night, and therefore lengthening the recording period. Recording at night and including some artificial lighting might also improve the problem of the background (Poursaberi *et al.*, 2010). In the current side view setup, a moving background can be seen. When the recordings take place at night with artificial lighting in the foreground, the background will remain dark.

In this study, three recording periods were performed in a two week period. Increasing the number of recordings to three or four times a week, or daily recordings may increase the number and quality of the records.

The incidence of lameness on this farm is small. In the next experiments, a larger herd size is recommended in order to increase the number of lameness cases. More cases will improve the accuracy of the detection method.

The experimental setup is made in a robotic milking farm, and not in a farm with a conventional milking parlour. This is mainly due to practical reasons. This farm is located nearby and it is what we have. This paper is the first step in a larger project that will be conducted in this farm. Robotic milking farms have also some advantages. First of all, they are heavily computerized, so it is easy to install and plug your hardware to the electrical circuit or internet in the farm. Second, in a robotic milking farm, the cows leave the milking parlour one by one, and not in one group. One exception to this last point is a "Tandem" milking parlour, but no such milking parlour can be found in this region.

Lame cows show an irregular gait when they walk. This irregularity may be characterised by an asymmetric walking pattern that can be seen from a top view angle. Therefore a camera in top view position is installed to capture this gait characteristic.

Conclusions

The results in our study show that in three sessions, 92.5% of the animals could be recorded when walking at least two full gait cycles on a predefined path. This allows us to find in future research an algorithm that can detect lameness in an early stage, based on gait characteristics.

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