Automating Heat Detection

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Abstract

This paper describes the development of the Dairymaster MooMonitor which is a new nanotechnology accelerometer based sensor to measure cows activity for the purpose of detecting estrus. One of the key advantages of using this measurement technology is that specific types of activity may be measured. The cow wears a sensor around the neck and this information is periodically downloaded to a receiver base station. This base station may be directly connected to a PC or via a mobile phone link where it can be located remotely. When the system detects cows in heat the cow may be drafted automatically, a voice message may be received in the milking parlour and an SMS text message may be sent to one or more users.

Introduction

Measurement of activity.

Wendl et al. (1995) showed that restlessness is an important external indicator for incidence of oestrus in cows. Schofield et al. (1991) evaluated significantly higher activity rates on the day of oestrus than on any other day. Historically electronic pedometers are available for automatically recording activity. Typically in these systems activity is measured by a mercury switch that is turned off and on by movement of the cow. When using a mercury switch to record activity generally better results were found on the leg. This was due to head movements contributing to the variation in data, however locating a sensor on the neck is more preferable as it is more hygienic and animal friendly. Much work on activity analysis in the past has focused on cows indoors.

The Dairymaster MooMonitor was designed to be very accurate in terms of measurement of specific types of activity which are associated with heat and is based on locating the device on the cow's neck. It was also considered very important to have success on pasture as this would be a key benefit of the system.

Accelerometer measurements.

An accelerometer is a device for measuring acceleration and gravity induced reaction forces. Single- and multi-axis models are available to detect magnitude and direction of the acceleration. An accelerometer measures the acceleration and gravity it experiences. Both are typically expressed in SI units meters/second2 (m/s2) or popularly in terms of g-force.

One of the most common uses for accelerometers is in airbag deployment systems for modern automobiles. In this case the accelerometers are used to detect the rapid negative acceleration of the vehicle to

determine when a collision has occurred and the severity of the collision. Another common automotive use is in electronic stability control systems, which use a lateral accelerometer to measure cornering forces. Accelerometers are used also in inertial navigation systems and are often used on military systems when sometimes there are temporary losses of GPS signals.

Following Einstein's equivalence principle the effects of gravity and acceleration the output of an accelerometer has an offset due to local gravity. This means that an accelerometer at rest on the earth's surface will actually indicate 1 g along the vertical axis. To obtain the acceleration due to motion alone, this offset must be subtracted. Along all horizontal directions, the device yields acceleration directly. The advantage of this is that inclination may also be measured using accelerometers.

Locomotion of cows

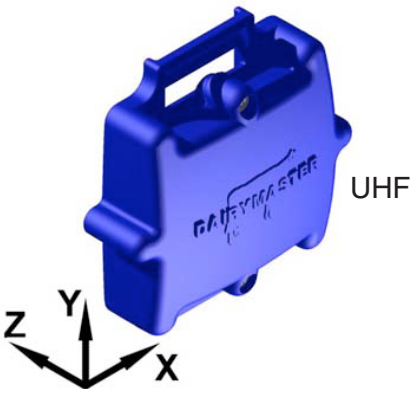
Locomotion of cows was studied using video imaging to determine the various behaviour types. During these studies a tri-axial accelerometer wireless data logging system was developed and data was superimposed on the video images.

Patterns of cows at rest, feeding and in estrus were analysed and algorithms were developed to record the intensity of these events at any point in time. By analysing the variation in activity and the vector direction of the effects of gravity the cows movement and head position could be determined.

Development of the MooMonitor.

MooMonitor sensor.

Based on the above studies it was decided to develop a miniature sensing system based on a single-chip UHF transceiver with an integrated high performance microcontroller which is designed for very low power wireless applications. This was coupled with a MEMS accelerometer. In this device mechanical sensing elements and electronics are integrated on a common silicon substrate through microfabrication technology.



The device makes a measurement of activity based on proprietary algorithms which can filter specific head movements. Activity associated with feeding is not registered as this is of no interest when trying to detect heat. The data is summarised on an hourly basis and stored within the MooMonitor. Based on a preprogrammed interval since last download and a priori knowledge of the milking times the MooMonitor searches for a base station to download data.

Base station.

The base station continually listens for MooMonitors and downloads all the data over the air. Typically it may be located either in the collecting area into the milking parlour or may be located near where the cows are housed. It has a typical range of about 100m. The advantage of locating the base station near the cows is that data may be obtained sooner and if cows are detected in heat it may notify the user earlier in the day.

GSM/3G mobile phone link.

In situations where animals may be at another off-farm location base stations may communicate with the PC using a mobile phone data link rather than a cable link. An optional interface board which allows connection with a 3G or GSM mobile phone system may be added to the base station.

System Schematic.

Data analysis and results.

Indoor and outdoor activity.

The average daily activity of cows was monitored on a number of trial herds. Cows on pasture have a much greater variation in activity compared with cows indoor (see Figure 1 and Figure 2). Cows on pasture are the most challenging from an automated heat detection viewpoint.

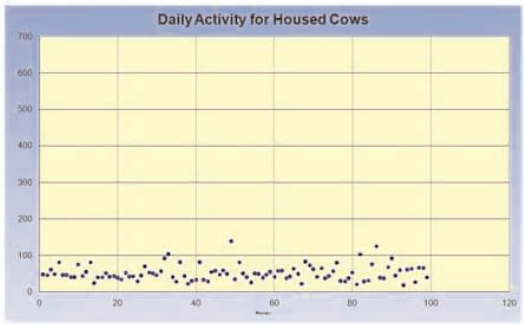


Figure 1 Daily activity for housed cows.

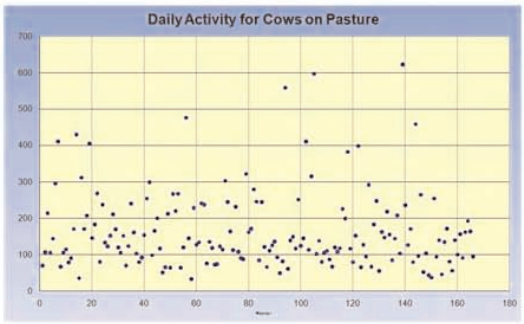


Figure 2 Daily activity for cows on pasture.

Normalisation, base lining and fuzzy logic.

There is a natural variation among animals in terms of their normal activity. In humans this is very obvious if you compare the activity of an Olympic athlete with that of an elderly person. With cows there are similar but less subtle variations.

In order to detect changes in the cow's activity it is important to baseline the cow against herself. In addition in order to take into account normal herd variation associated with greater walking distances, particularly when outdoors it is necessary to baseline each cow with their group. These data series is computed for each hour of the day and input into a fuzzy logic model. The model makes a determination if a cow is in heat or not.

Software.

The PC software communicates with the base station and downloads the data for the analysis either in real time or based on a predefined schedule (for remote sites).

The MooMonitor Data Analysis tool performs the computations described above and can send a text message to one or more users. It can also inform the Dairymaster Milk Manager parlour system about cows to be drafted or for which cows a voice alert may be issued. This means that when these cows appear in the parlour a voice alert may be issued to the user, a message will appear on the milk meter display and the cow can be automatically drafted in to the desired pin.

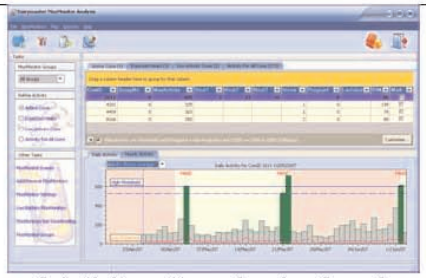


Figure 3 Activity pattern showing 3 week cycle.

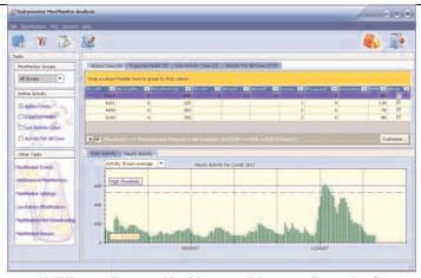


Figure 4 Hourly activity pattern, heat shown on right side.

Scientific field evaluation – Progesterone analysis.

In April 2007, 173 cows in Teagasc's Moorepark Ballydague farm (Co. Cork, Ireland) were fitted with Dairymaster MooMonitors. Milk samples were collected for progesterone analysis from all cows for the first six weeks of the breeding season to allow accurate identification of when cows were in heat. At the end of the study, heats identified by the MooMonitor activity meter were compared against heats confirmed by the milk progesterone data. During the monitoring period, the MooMonitor device correctly identified 82% of the

heats that occurred, and had an error rate of 6.8% (i.e seven out of every 100 cows were incorrectly identified as being in heat). This is very good performance for measurements with cows at pasture.

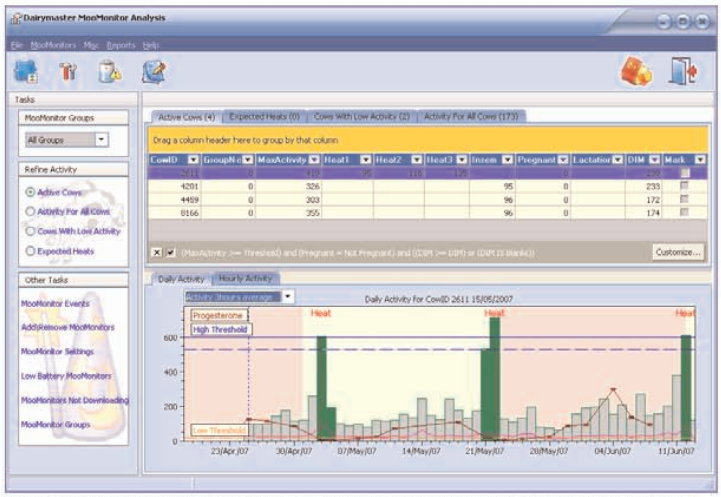


Figure 1 MooMonitor data with progesterone profile shown in red.

Scientific field evaluation – Heat Start Time.

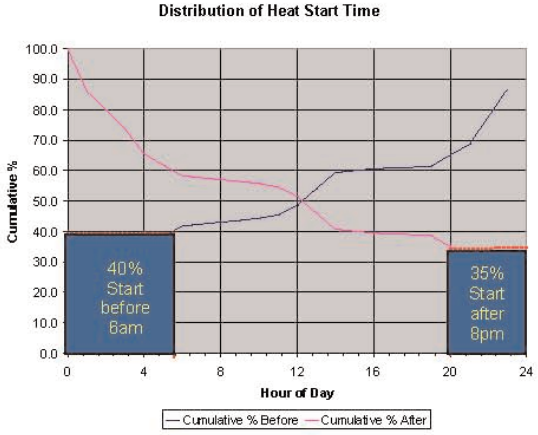


Figure 6 Heat start time cumulative distribution.

Figure 6 shows that based on activity measurements 40% of heats start before 6am and 35% of heats start after 8pm. This means that 75% of increases in activity occur when the herd is not monitored. This is a key advantage of the MooMonitor in that it monitors cows 24 hours per day and this information can be acted upon sooner.

Economics.

There are many models for estimating the costs of missed heat detection. These often take into account milk production losses, cost of replacement animals, the loss of genetic improvement and increased AI and labour costs. In Ireland missed heats are estimated to cost ?11 per cow per day or ?231 per missed heat. Based on these costs the system can often pay for itself in 1-2 years depending on individual circumstances.

Conclusions.

- The Dairymaster MooMonitor is a technologically advanced method of monitoring estrus in cows.
- It may be used on the main farm or in an off-farm location for cows indoor and outdoor use.
- Many heats start at times when cows are least observed. It was shown that 75% of increases in activity started between 8pm and 6am.
- In scientific trials it showed an 82% automatic heat detection rate and 6.8% error rate.
- The user may receive text messages, voice alerts and cows may be drafted automatically if integrated with parlour management systems.
- In many cases it can have a return on investment in 1-2 years.

References.

Wendl, G., Klindtworth, K., Wagner, M., 1995. Einsatz von Aktivitätssensoren und injizierbaren Transpondern mit integriertem Temperatursensor in der Milchviehhaltung. 46th Annual Meeting of the European Association of Animal Production, Prague, Czech Republic, 4–7 September, 1995. C4.6.

Schofield, S.A., Phillips, C.J.C. and Owens, A.R., Variation in milk production, activity rate and electrical impedance of cervical mucus over the oestrus period of dairy cows. Anim. Reprod. Sci. 24 (1991), pp. 231–248.