Automated electronic activity measurement for oestrus detection of dairy cows

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Abstract
Sensor measurements of the activity can be used in dairy cattle breeding for the detection of oestrus. A new on-line information system has been developed in which the traditional pedometer is replaced by a sensor for full activity (mobility). Results for the hour activity of a dairy cow during different periods of the lactation are presented. A recurrence hour activity model for detection is proposed. It is based on statistical analysis of time series models and Kalman filter.

1 Introduction

The help of computer systems for observation of animals is a basic premise for an increase of the productivity of the dairy cows. Sensor measurements are mostly used for detection of oestrus, pregnancy, early recognition of mastitis and other diseases. The researches up to now of Wendl (1998), Breme et al. (1999), Radev (1999) show that the parameters of computer monitoring in the farming can be divided into two basic groups (see Figure 1).

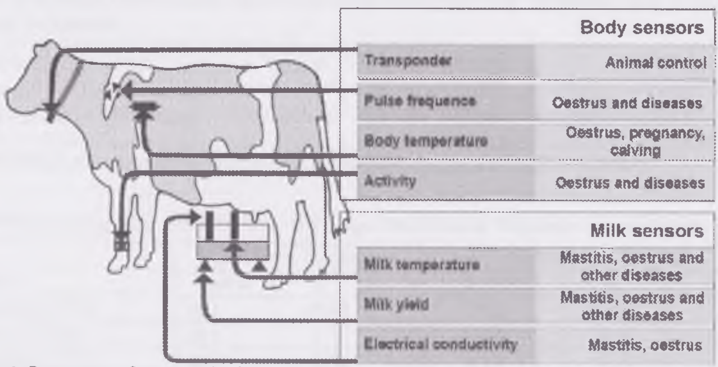

Fig.1. Parameters of computerized process monitoring in dairy farms

Further efforts should be concentrated on the following objectives:

- Reducing the number of the sensors on the body of the animal – testing an "integral sensor";
- Development of "advanced sensors" especially when milking;
- Processing the data with the help of intelligent systems.

The efforts of the University of Rousse are concentrated on research of a "full activity" sensor, which is implemented in a system for automatic observation of oestrus, as a first step along these lines.

2 Material and methods

The investigation takes into consideration the two characteristic periods of dairy cow breeding in the Bulgarian farms:

- Winter – the classical technology for tied stall barn (November-March);
- Summer – most of the daytime the cows are out of the cowshed at grass-feed (March-October). The milking is in the same way like in the tied stall barn (2-3 times daily).

An on-line oestrus monitoring system is developed Radev et al. (2000), in which the traditional pedometer is replaced by a "full activity" sensor. The data of the activity of the examined cow are recorded and stored in EEPROM memory at every hour (see Figure 2). Wireless transmission to the PC, using RF-technology is done during the time of milking.

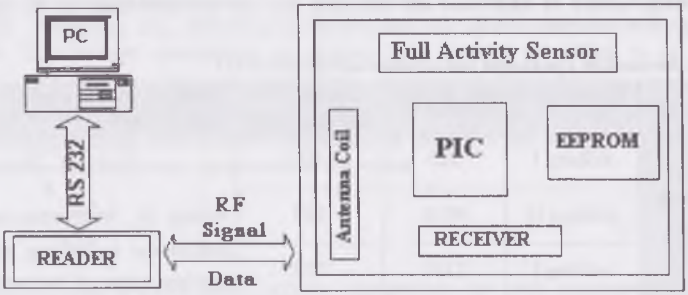

Fig. 2. Monitoring hardware system

The management information system (MIS) automatically generates warning-lists at time of oestrus, which are based on signals, received from the sensor. MIS uses database in which the normal characteristics of the measured variable are described. Each cow gets her own model of activity. The parameters of the model are evaluated and corrected after each milking.

3 Hour activity of dairy cows

The investigation was carried out in an experimental farm of the Regional selection and reproduction department in Rousse for the period of one summer. Sixteen Holstein Friesian cows were under observation around the oestrus days. Their activity is measured in two ways:

✓ by on-line monitoring system and attached to the cow's neck a "full activity" sensor (Conrad Electronics N: 700444-25);

✓ by attached to the cow's leg pedometer (type Zarya, Bulgaria), which with the help of a mechanical counter gives the number of steps between two milkings.

The average hour activity $\overline{A}_h$ (in S/h) is calculated for comparison of the two activity models.

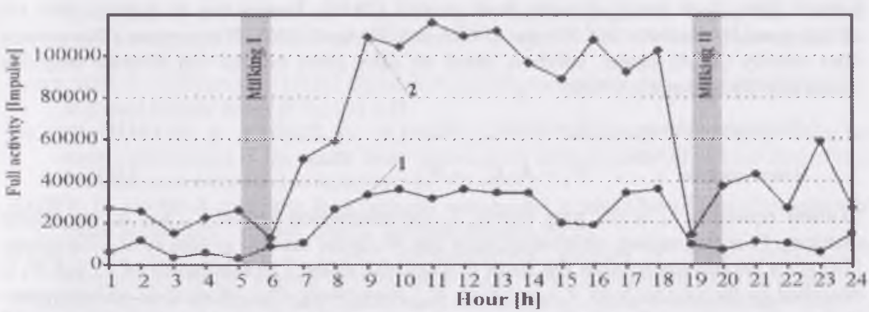

Fig.3. Hour activity of cow 329, measured by a "full activity" sensor: 1-normal rhythm, 2-rhythm in oestrus day

There are essential differences in the hour activity during the day in the cow breeding during the summer period. During the nature grazing (from 7 to 19 o'clock) the "full activity" sensor detects an increase from about 600 to 1000% (see dependence1, Figure 3). These values are even bigger than the increase of the activity rhythm during the nature grazing in oestrus day (see dependence 2, Figure 3). The tendency although weakly expressed is observed also at measuring with a pedometer.

In the oestrus day the calculated hour activity increases between 150 and 300% (see Table 1). The alteration of the average hour activity during the nature grazing is about 400%. Of course the activity values of each cow are different, but the characteristics of the alteration are similar.

Table 1. Measured by a pedometer and calculated activity of cow 329

Lactation	Measured activity, [Step]		Average hour activity, [S/h]	Equation for calculation average hour activity
before oestrus	milking I	920	92	$\overline{A}_h = \frac{N_n - N_{n-1}}{p}$, where: N_n, is counter value of the pedometer in milking n; N_{n-1}, is counter value of the pedometer in milking n-1; p, is number of hour between two milkings.
	milking II	4830	345	
in oestrus	milking I	2320	232	
	milking II	9240	660	

Based on our results received from 462 milkings and 42 oestruses of different cows, the following general conclusions can be made :

- During the nature grazing the cow activity increases considerably. The alterations in its normal behaviour rhythm are commensurable with the increase of the activity in oestrus day. This can cause serious mistakes at generating of the oestrus warning-list;
- With a pedometer the possibility for mistake at generating of oestrus warning-list is bigger;
- The hour activity measurements give a more reliable and complete information than the measurements of the number of steps between two milkings.
- The possibility for integrating with other physiological parameters is the priority of the "full activity" sensor.

4 Time series models for oestrus

The information processing is based on statistical analysis of time series combined with a Kalman filter. Such steady dynamic linear models (DLM), known also as Kalman filter are already used by Harrison and Stevens (1976) and Thysen (1993). We propose a Recurrence hour activity (RHA) model, which is based on dairy cows oestrus and diseases detection model (see De Mol et al., 1999):

Observation equation: $$Y_n = C_n . X_{n-1} + V_n; \quad (1a)$$

System equation: $$X_n = A_n . X_{n-1} + W_n; \quad (1b)$$

In these equations X_n is the state vector, Y_n the observation vector, C_n and A_n are system matrices, V_n is the random observation error and W_n is the random system error. The system (1b) gives the relation between the states at successive times. The distribution of V_n and W_n is described by the vectors N (0, V_n) and N (0, W_n) respectively. Our information on-line system registers the activity of each cow for every astronomical hour therefore the activity model becomes:

$$A_h = \frac{\sum_{i=1}^{k} A_i}{k} \quad (2a) \qquad \Delta A_h = A_{h,n} - A_{h,n-2} = Z_{\alpha,n} - \alpha . Z_{\alpha,n-2} \quad (2b)$$

Where: A_h, is the average hour activity; A_i, hour activity; k, number of hours between two successive PC recordings; ΔA_h, difference of the average hour activity between milking n and milking n-2; $Z_{\alpha,n}$, random disturbance on average hour activity at milking n; α, model parameter.

We use an additional parameter μ in the system vector to increase the accuracy of the model. The hypothesis for average hour activity comparison at milking n and milking n-1 is checked by this parameter. The following vectors define the model:

$$X_n = \begin{bmatrix} -\alpha \\ -\mu \end{bmatrix} \quad Y_n = \begin{bmatrix} \Delta A_h \\ \Delta A_n \end{bmatrix} \quad Z_n = \begin{bmatrix} Z_{\alpha,n} \\ Z_{\mu,n} \end{bmatrix} \qquad (3)$$

Where: ΔA_n, is the average hour activity comparison in two successively on-line measurements; $Z_{\mu,n}$, random correlation on activity at milking n.

By observing the average activity correlation during two successive milkings, the possibility for mistake at generating of oestrus warning-list decreases:

$$\Delta A_n = \frac{A_{h,n}}{A_{h,n-1}} = Z_{\mu,n} - \mu . Z_{\mu,n-1} \qquad (4)$$

The model estimation procedure is standard for the Kalman filter with two stages - estimation of system vector X_n based at its previous state X_{n-1}; updating the estimation with the observation Y_n and estimating the error.

The accuracy of the proposed RHA model increases by increasing the number of the observations on the measured variable. It is suitable to be used in intelligent system for on-line physiological parameters observation of dairy cows (for instance body temperature, temperature and electrical conductivity of the milk, milk yield). The preliminary results, which have been obtained, give reasons to continue the research along these lines.

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