Computers and Electronics in Agriculture
24 (1999) 91–98

Computers
and electronics
in agriculture

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Animal identification and monitoring

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Abstract

Devices for electronic animal identification, becoming available in the mid-1970s, facilitated the implementation of sophisticated livestock management schemes. The standardisation by IOS of the next generation of injectable electronic transponders opened a world-wide market for all species of animals. The third generation, currently under development, includes also read/write possibilities and sensor technologies for automatic monitoring of animal health and performance. The addition of these sensors facilitates the automation of sophisticated tasks such as health and reproduction status monitoring. Examples are given of the automated oestrus detection by signal processing of one or more sensor signals. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Identification of animals; Monitoring of animals; Oestrus detection

1. Introduction

By the mid-1970s experiments had been carried out with electronic transponders for individual feeding of cows and automatic data recording (Rossing, 1976, 1978). The electronic 'black boxes' (first generation) were attached to collars attached around the neck. Later on, further miniaturisation of electronics allowed the development of tiny electronic transponders, which could be injected under the skin (second generation). Also the price declined dramatically. Because of the many logistical and tactical benefits of electronic animal identification, a world-wide market could arise for this application, primarily for agricultural animals, but also for companion and zoo animals. This necessitated the standardisation of codes and interrogation techniques. For this purpose, IOS came up in 1996 with two stan-

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PII: S0168-1699(99)00039-3

dards: ISO 11874 for the 64-bit code structure and ISO/11785 for the combined FDX/HDX interrogation protocol, working at 134.2 kHz (Eradus, 1993, 1998; Eradus and Rossing, 1994).

The third generation, currently under development, includes also read/write possibilities for storage of the (medical) history of the animal and sensor technologies for automatic monitoring of animal health and performance. Moreover, advanced third generation transponders can also be provided with authentication protocols to prevent fraudulent copying of transponder codes. IOS is also developing a standard for this new generation, which will be compatible with the existing standards. As an illustration, Fig. 1 shows the basic components of an RFID system.

2. Electronic identification

Electronic identification of cattle usually referred to as RFID (radiofrequency identification), has many advantages for farm management. First, it can be regarded as a considerable improvement in relation to visual identification of numbers. The main advantages are the elimination of labour costs (Artmann, 1993) and the decrease of incorrect readings from 6% to 0.1% (Austin, 1995; Geers et al., 1997). RFID also facilitates the use of automated housing systems (Geers et al., 1997) and combines the advantages of the conventional loose housing systems (relative freedom for the animals) with the advantages of the stanchion barns (control of single animals) (Bockisch, 1990)

Sophisticated livestock management schemes can be implemented by allowing the automation of, for example, feed monitoring and rationing, weighing and drafting (Hurst et al., 1983). Cattle management will be carried out on basis of the individual animal: performance recording (Geers et al., 1997), dispensing of feed, geographic routing dependent on the animal status. Examples are robot milking and the implementation of geographic information systems to assess the potential transmission of infectious diseases between herds (Geers et al., 1997).

Also from the point of view of return on investment, RFID systems seem to be a good solution. It is expected that the total cost for recording per animal in the database will decrease by 50% when using RFID in combination with a central

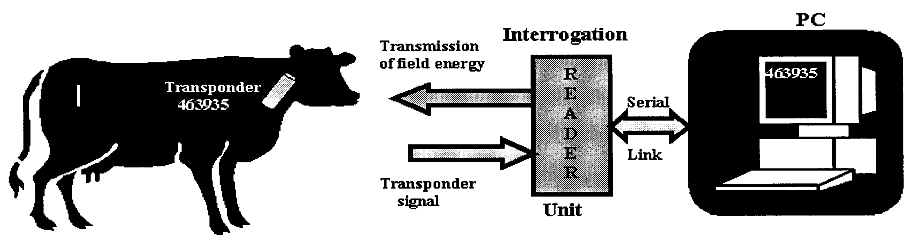

Fig. 1. System overview radio frequent identification of animals (Geers et al., 1997).

database (Wismans, 1994). Other important applications enabled by injected electronic transponders are improvement of disease control and eradication as well as fraud control. The latter application is very important within the European Union (EU), where premiums are being paid to stimulate extensive sheep and beef production. Also within the EU, it is not longer allowed to eradicate some contagious diseases by means of vaccination. In case of an outbreak, it is very important to trace back the origin, movements and contacts between animals to be able to stop the further dissemination of contagious diseases (Geers et al., 1997).

In practice, RFID implementations can give rise to several problems. Reading speed and distance must be optimised for specific applications. The International Committee for Animal Recording (ICAR) developed in 1995 a set of requirements regarding (among others) the reading distance and reading speed (Geers et al., 1997). Error-free reading should be possible at a distance of 0.4 m while the animal is moving with a speed of 3 m/s. With modern transponders reading ranges up to 0.8 m and reading speeds up to 4 m/s proved to be possible (Klindtworth, 1998), thus fulfilling these requirements. Other issues include biocompatibility of encapsulation (Rocha et al., 1993), the injection site in connection with migration problem, recovery in slaughterhouses, and the open trade that necessitates standardisation and proper, effective management of issued unique life-numbers.

3. Electronic monitoring

RFID plays a key role in electronic monitoring systems, which are inherently related to sensing systems. This combination makes it easier to switch from intensive to semi extensive animal husbandry systems (e.g. group housing of sows) (Geers et al., 1997).

Integration of on-animal sensing devices opens possibilities for the automation of sophisticated tasks such as health monitoring and reproduction status (oestrus, pregnancy) (Hurst et al., 1983). Some examples: transponders equipped with a temperature sensor (Nelson, 1988; Geers et al., 1997), or in combination with activity tracking (Artmann, 1993). The accuracy of these implanted temperature sensors is about 0.2°C. Because in most cases not the absolute values, but just the relative changes contain the significant information, the resolution must also be specified. Because of the digital representation of the temperature measurement, it is necessary to provide the result with at least one decimal place.

Sensor-based transducers also have been developed in Leuven within the framework of ÉCLAIR-AMIES project, monitoring the body temperature, the ECG signal and the pH value (Villé et al., 1993). These sensors have been used to monitor stress on piglets during transportation.

The sensors are both the strength and the weakness of the monitoring concept. Typical performance aspects are the selectivity, the accuracy/resolution and long-term stability. In particular sensors with selective bio-interfaces can cause stability problems (Puers, 1993; Geers et al., 1997). An example of this class of biosensors is the interface with the enzyme glucose oxidase (GOD) for glucose detection.

Improvements have been achieved with immobilising techniques (Puers, 1993; Geers et al., 1997). Because the sensor circuitry of these advanced devices requires a more or less continuous energy supply, small (mostly Lithium based) batteries have to be integrated in the transponder. Despite the application of very low power electronics (Eichinger and Stemrau, 1993), the lifetime of such devices is limited. One improvement to extend this lifetime is dual powering, i.e. using an internal battery for measurement and storage of data together with external an external radiating power source for transmission of data to the reader, as developed by Leuven within the framework of EU contract (Geers et al., 1997). An alternative concept is to use an external radiating powering source for both the interrogation and the (semi)permanent activation of the sensor circuitry, thus enabling unlimited use of the sensor/transponder (Eradus, 1997).

4. Applications of RFID in combination with monitoring

As described, for farm management, the farmer will get more profit from an identification and monitoring system than from identification only (Geers et al., 1997). One of the first applications of an electronic monitoring system was the measurement of the physical activity of milking cows, in order to detect oestrus (Rossing et al., 1983). For this purpose actrons or pedometers were attached to a halter around the cow's head, enabling the identification number to be registered together with the activity level by interrogation of the device in the milking parlour. Later on, more parameters correlating with the occurrence of oestrus have been taken into account. Besides activity measurement, also milk yield, milk temperature, electrical conductivity of milk and heart rate have been measured in order to improve oestrus detection (Schlünsen et al., 1987). In the same way, automatic systems monitoring udder inflammation or mastitis have been developed, based on changes in the electrical impedance, milk yield and milk temperature of the (quarter) milk (Maatje et al., 1992).

The accurate measurement of parameters is a necessary but not sufficient condition for developing a reliable monitoring system. In practice it proves difficult to interpret the signals in an optimal way. Some approaches are restricted to visualising the data by presenting lists of deviant values or visualising the data in a graphical way. As an example, Rossing et al. (1989) have proposed a mastitis monitoring system where deviations in milk conductivity, milk temperature and milk production are marked with one or more asterisks (*) depending on the magnitude of the deviations. It is up to the farmer to interpret this information. This relatively simple approach however requires a long learning time and still remains suboptimal.

In the literature a lot of different detection algorithms are reported which have been developed and evaluated. At the Federal Research Centre of Agriculture (FAL) in Braunschweig, statistical discriminant analysis has been used for the development of an automatic detection system for oestrus in dairy cows. The output is a weighted sum of the input parameters, milk temperature, activity, milk

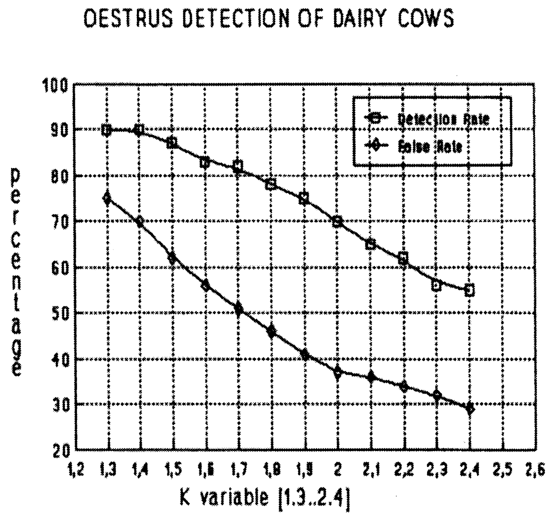

Fig. 2. Detection rate and false rate depicted as functions of the threshold ratio of the peak detector.

yield and heart rate. The weighing factor is determined by the relative importance of the parameter concerned. Using this method, a detection rate of 90% in combination with an false rate lower than 10% have been reported (Schlünsen et al., 1987).

At the Institute for Environmental and Agricultural Engineering (IMAG-DLO), a number of different detection algorithms have also been evaluated. Based on the knowledge that the activity of cows peaks during the occurrence of oestrus, an optimised peak detection system has been developed. Only the counts registrated by the pedometers, read during milking time have been used. It has been demonstrated that the detection and false rates are related (see Fig. 2). Choosing a detection rate (the percentage of detected heats) of 90% implies a false rate (the percentage of incorrect alarms) of 70% and conversely, a low false rate of 37% restricts the detection rate to 70%. (Eradus et al., 1992).

De Mol et al. (1997) have described a very comprehensive monitoring system both for automated oestrus and for mastitis detection. The model is based on multivariate time series analysis combined with Kalman filtering techniques.

Alternative methods being evaluated are the reasoning approach using fuzzy logic and the learning approach using a neural network paradigm (Eradus and te Braake, 1994; Eradus et al., 1998). Both methods proved to be suitable to cope with the handling of uncertain or subjective information. One of the advantages is the inherent possibility to combine more sensor-signals that are related to oestrus (sensor-fusion). The first method is based on experience, the latter method principally requires no a-priori knowledge. As an illustration, this neural network approach applied to oestrus detection will be described in more detail.

To evaluate the possibilities of neural networks for the detection of oestrus the well-known feed forward paradigm with one hidden layer has been chosen, with a very fast learning algorithm (te Braake, 1992).

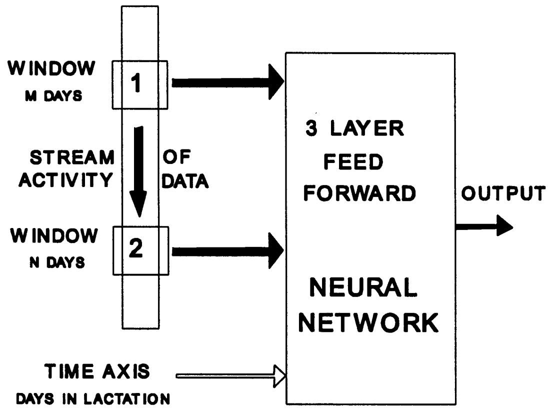

Fig. 3. Input configuration of the neural network for oestrus detection using activity data.

The detection problem is to recognise special patterns in a time series of activity data. To make optimal profit from the learning capacity of a neural network, pre-processing of the raw data is necessary: normalisation of the data and the use of gradients rather than absolute values are the first steps. But it is also important to work up as much as possible a-priori knowledge in the pre-processing stage. With respect to oestrus phenomena in dairy cattle, the fact that it has a periodic character (mean repetition interval of 21 days) can be exploited. This can be done with a proper choice of the input data: one input window (1) contains the activity of the last M days and another input window (2) with a length of N days is centred around the 21st previous day (see Fig. 3). If a significant increase in the activity level in window 1 coincides with a peak in window 2, the network can learn that a new oestrus will occur. In order to make the response of the network dependent on the number of days in lactation, time has been added as an extra input. Especially at the beginning of the lactation, after calving, the detection of the first oestrus requires another network response, because no previous oestrus peak can occur in window 2.

After training with a data set with 140 heats from 32 cows and testing the network with a data set with 25 heats from six cows the preliminary performance results were:

- Detection of the first oestrus: detection rate 75% and false rate 30%.
- Detection of next occurrence of oestrus, given that the first oestrus has been detected: detection rate 90% and false rate 10%.

5. Conclusions

Devices for electronic animal identification facilitated the implementation of sophisticated livestock management schemes, with optimal attention and freedom for the individual animal.

The standardisation by IOS of the next generation of injectable electronic transponders opens a world-wide market for all species of animals. The third generation, currently under development, includes also read/write possibilities and sensor technologies for automatic monitoring of animal health and performance. The addition of these sensors facilitates the automation of sophisticated tasks such as health and reproduction status monitoring.

This requires appropriate signal processing techniques, like the described neural and fuzzy methods as well as multivariate time series analyses.

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