AUTOMATIC ON-LINE MONITORING OF ANIMALS BY PRECISION LIVESTOCK FARMING

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1. Objectives of Precision Livestock Farming in monitoring

Livestock production today is no longer limited to obtaining economic goals. Modern society is concerned about food safety and quality, efficient and sustainable animal farming, healthy animals, guaranteed animal well being and acceptable environmental impact of livestock production. As a consequence, there is a growing need to monitor many variables during the entire production process in order to satisfy these targets. In the past, livestock management decisions have been based almost entirely on the observation, judgment and experience of the farmer (Frost et al., 2003). However, together with the increasing scale of the farms and the corresponding high number of animals, this evolution has resulted in an increasing administrative, technical, organisational and logistic workload for the farmer and has limited the possibilities of the same farmer to monitor his animals by himself.

Observation by ethologists is needed for research purposes, but is very expensive for practical application and has the disadvantage of limited time period of observation. Today, automatic monitoring and controlling techniques are becoming more and more important to support the farmer in managing the production process. Although biological processes involving living organisms have always been considered as too complex to be monitored and controlled in an automatic way, today new emerging technologies offer possibilities to develop full automatic on-line monitoring and control of many of these processes.

One of the objectives of Precision Livestock Farming (PLF) in the field of monitoring is to develop on-line tools to monitor farm animals continuously during their life, in a fully automatic way, with objective measures and criteria calculated on-line from collected data and without imposing additional stress to the animals. The aim of these technical tools is not to replace but to support the farmer who always remains the crucial factor in good animal management. Besides on-line automatic monitoring, PLF offers also interesting possibilities in automatic control for supporting the management of such complex biological production processes (e.g. feeding strategies, growth rate control, activity control, see Morag et al., 2001; Halachmi et al., 2002; Aerts et al., 2003a, b; Kristensen et al., accepted).

2. Basic principles of Precision Livestock Farming

The PLF approach starts from the observation that the animal is the most crucial part in the biological production process in an animal house. Despite this fact, in most modern livestock houses worldwide farmers use control equipment (e.g. climate control, feeding supply etc) that does not measure anything on the most important part of the process: the animal.

Animals, as all living organisms, are *complex*, *individually different* and *time-variant* (meaning that they respond differently at different moments of time). Therefore, we say that animals are CIT systems (Complex, Individual and Time-variant).

A starting point in PLF is the recognition that each individual animal is such a CIT system. This contrasts with more classical approaches where animals are considered as “an average of a population and due to its complexity as a steady state system”.

For monitoring and control of livestock production processes, the PLF approach makes use of modern monitoring and control theory. To achieve favourable monitoring and control of such processes, *three conditions must be fulfilled.*

The *first condition* to be fulfilled is that *animal variables must be measured continuously* and this information is analysed continuously. “Animal variables” can be very different such as weight, activity, behaviour, drinking and feeding behaviour, feed intake, sound production, physiological variables (body temperature, respiration frequency, blood variables,). What “continuously” means is depending on the measured variable such as 25 times a second when monitoring on-line animal activity from video images or a sample every day when monitoring animal weight.

A *second condition* to realise accurate animal monitoring and management is that at every moment *a reliable prediction (expectation) must be available* on how the animal variables will vary or how the animal will respond to environmental changes. By environment we mean the whole of all variables that are not genetically defined. It is the continuous comparison between this prediction (in the past the experience of the farmer and now for example a mathematical model) and the actual measured values that allows to identify animal activities and to judge when something abnormal is happening.

The *third condition* is that this prediction together with the on-line measurements are integrated in an analysing algorithm (a number of mathematical equations implemented in a microchip) to monitor or manage the animals automatically and to achieve on-line monitoring of animal health, welfare, or take control actions (climate control, feeding strategies,). A schematic overview of the three conditions is shown in Fig. 1.

Since the animal is acting as a complex, individual and time varying system we need to apply this PLF approach in an appropriate way. The best way to handle this time-variant character of all the complex individual animal responses is by applying continuous measurements and predictions and by using predictions and applying mathematical data-analyses in an on-line or real time way and, if possible, on individual animals. The required technology is available. The key to realise this application is novel and innovative multidisciplinary research.

3. Sensors and sensing techniques

The last years, many research and development efforts have been done all over the world to develop new sensors and sensing techniques to acquire on-line information from animals and to collect different animal variables. For cows, pigs and chicken several sensors, sensing principles and sensing techniques have been described in literature. As shown before (Berckmans, 2003) we have found in recent literature 11 papers to measure eating behaviour, respiration rate, non destructive chewing behaviour, stress responses, etc. for pigs (e.g. Eigenberg et al., 2000). For cows, 29 sensors are described in recent literature to measure deep body temperature, body weight, udder health, oestrus, breath emissions, biting rate in grazing cows and others (e.g. Velasco-Garcia and Mottram, 2001). For chicken's recent literature gives 9 papers describing sensors to measure body temperature with radio transmitters, biosensors to detect pathogenic bacteria at very low levels, heat stress and others (e.g. Lacey et al., 2000). Twenty papers were found about vocalisations of pigs to measure variables such as: pigs need for supplemental heat, peripheral endocrine stress responses, behavioural responses to separation, on-line detection of infection of the respiration system (e.g. Marchant et al., 2001).

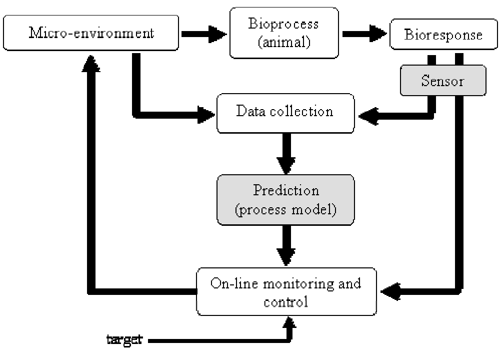

Figure 1. Precision livestock farming (PLF) by integration of measured bioresponses together with a predictive process model into a model-based monitoring or control algorithm: a schematic overview (Aerts et al., 2003a).

Twelve papers were found about the vocalization of cow sounds to measure animal's condition, effects of separation on behavioural responses, milk production, and identification of individual cows (e.g. Weary and Chua, 2000). Eleven papers were found on vocalization of chicken describing: an increasing number of gakel-calls with an increasing hunger state, stress dependence of chicks call qualities, capacity to emit food calls and quantification of stress (e.g. Zimmerman et al., 2003). Nineteen papers describe image analysis of pigs to measure: location of pigs in scenes, stress conditions, tracking of piglets, relation of outside 3 dimensional body conformation and lean-fat ratio, on-line monitoring of pig weight (e.g. Onyango et al., 1995). Twenty seven papers describe image analysis of chicken for real time disease detection, behavioural responses, non-destructive prediction for yolk-albumen ratio in chicken eggs, feeding behaviour, animal distribution and activity and automatic identification of activities related to animal welfare, animal weight (e.g. De Wet et al., 2003).

It can be concluded that several efforts are done to develop sensors and sensing techniques for animal variables and this is just a beginning stage. Many new sensing systems will be developed in near future (sensors at the micro- and nano-scale, biosensors, telemetry, etc.).

Today, the availability of reliable and accurate sensors still is the main bottleneck to apply PLF in practice. The price of this new technology is not a main problem since as shown by many examples (CD player, mobile phone, GPS) the number of produced units is the main factor influencing the price.

4. Exemplar 1: Real time sound analysis to detect health status in pigs

A first example of PLF in monitoring animals is a system to detect infections in fattening pigs by on-line analysis of their produced sound. The basic idea is that the respiration system is producing a sound when coughing. When the animal is infected by a respiratory disease, the characteristics of the respiratory system, such as the cell of the air pipes, are changing. Consequently, the characteristics of the energy in the sound signal that is produced when air is pulsed through this system, when coughing, will be different as well. If this difference in sound signal can be detected fast enough after infection, on-line monitoring of pig's coughs and other animal sounds could be useful as a biomarker for infection and improve disease management (resulting in, among others, reduced antibiotics usage) (see also Fig. 2).

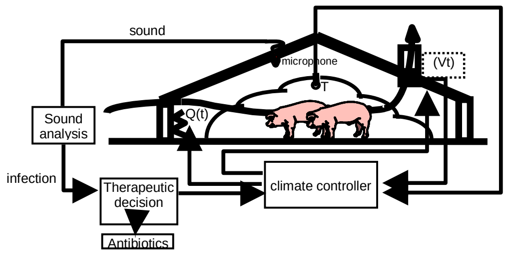

Figure 2. Use of on-line sound analysis as a basis for health monitoring in pigs.

Algorithms have been developed to detect coughs of pigs out of a raw sound signal (Van Hirtum et al., 1999; Chedad et al., 2001). In a first step, these algorithms make a distinction between a sound and no sound. Secondly, the sounds are classified in coughs and no coughs (other sounds) and finally also a distinction can be made from healthy and sick coughs (Van Hirtum and Berckmans, 2002) (cf. Fig. 3).

Based on laboratory experiments, it could be demonstrated that pig's coughs could be classified correctly in 94% of the cases (Van Hirtum and Berckmans, 2003). Testing of the developed algorithms in practice, showed that in pig houses in the field the coughs could be correctly classified in 86% of the cases (Guarino et al., in press; Jans et al., accepted).

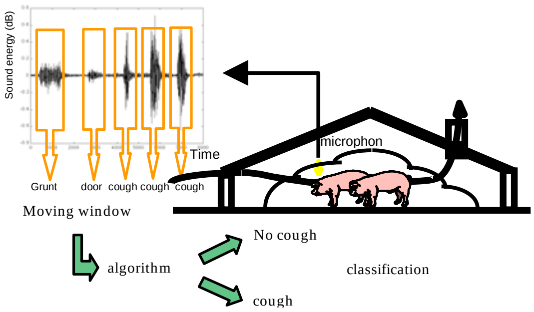

Figure 3. Classification of pig coughs.

5. Exemplar 2: Real time identification of the behaviour of laying hens to monitor animal welfare

A second example of PLF in monitoring animals, is a system to monitor fully automatically the activities of laying hens to score their welfare and to use this information for better managing the production process environment (cf. Fig. 4).

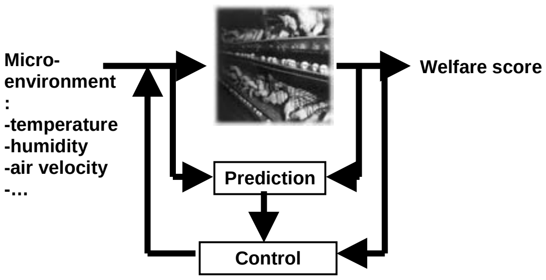

Figure 4. Integration of on-line monitored welfare score in the management of production processes for laying hens.

Behavioural characteristics are usually evaluated by audio-visual observation done by a human observer present on the scene. This method is time consuming, expensive and cannot be done continuously during the life time of the animal. Automated objective surveillance, by means of cheap cameras and image-processing techniques, has the ability to generate data providing a continuous measure of behaviour, without disturbing the animals. A fully automatic on-line image-processing technique was developed to quantify the behaviour of laying hens as opposed to the current human visual observation. The classification of the hen's behaviour was performed by dynamical analysis of a set of measurable parameters, calculated from the images using image processing techniques. A first implementation of the system allowed identifying three different types of behaviour (standing, walking and scratching) (Leroy et al., 2003). In Fig. 5, an example is shown of automatic scratching detection based on the developed algorithm (see also *http://www.labr.be*).

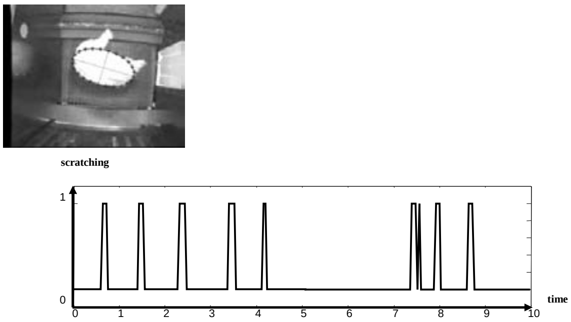

Figure 5. Automatic detection of scratching behaviour for laying hens.

6. Conclusions

Precision Livestock Farming involves the measurements, predictions and data-analyses of animal variables. PLF offers totally new possibilities to collect and analyse data from farm animals in a continuous and fully automatic way. We cannot only replace the farmers "eyes and ears" to each individual animal as in the past, but several other variables (infections, physiological variables, stress, etc) will soon be measurable in practice. The bottleneck to apply this technique is in the availability of reliable sensors and sensing systems, since it has been shown that the required mathematical algorithms can be developed.
The application of this technology offers new possibilities to realise food safety and quality, efficient and sustainable animal farming, healthy animals, guaranteed animal well being and acceptable environmental impact of livestock production.
Therefore, efforts should be increased for bringing this challenging approach of Precision Livestock Farming to practice. This is only possible when teams from different research disciplines, such as physiology, ethology, nutrition, hygiene, engineering, etc. join their research efforts.

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