Precision livestock farming for pigs

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Introduction

To guarantee accurate and continuous monitoring of individual animals at a modern livestock farm, farmers nowadays need reliable and affordable technologies to assist them in performing daily management of tasks. The application of the principles and techniques of process engineering to livestock farming to monitor, model, and manage animal production is called precision livestock farming (PLF). Precision livestock farming seems like the only realistic way to support farmers and other stakeholders in the livestock production chain in the near future while at the same time coping with the rising demand for meat.

Precision livestock farming is a series of practices aimed at increasing the farmer’s ability to keep contact with individual animals despite the growing intensification of livestock production. It aims to achieve economically, environmentally, and socially sustainable farming through the observation, behavioral interpretation, and control of the smallest possible group of animals. It enables farmers to reduce operational costs such as expenditures to feed, medication, and energy. Moreover, farmers can use PLF technologies to monitor animal health and welfare to ensure that animals live well and are free of diseases. Precision livestock farming systems aim to translate the measured animal responses into key indicators for optimal performance, improved animal welfare, and farm sustainability.

In a further development phase, PLF applications assist farmers in taking their daily management decisions and generate early warnings when something is going wrong in the production process. Attention must be paid to adequate training of farmers and the further integration of PLF system in operational management systems.

Implications

It was demonstrated that laboratory-developed precision livestock farming (PLF) tools can be fully operational on farms and can bring value to the farmers and other stakeholders in the production chains. In the PLF concept, the animal is used as a sensor, and algorithms translate the measured animal responses into key indicators for optimal performance, improved animal welfare, and farm sustainability.

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Examples of Precision Livestock Farming Systems for Pigs

In the PLF approach, the traditional environmental measures (temperature, humidity, and CO₂) are extended with direct measures of animal responses by means of feed intake sensors, growth monitors, cameras, and microphones. In this concept, the animal is used as a sensor, and algorithms translate the measured animal responses into key indicators for optimal performance, improved animal welfare, and farm sustainability.

In a further development phase, PLF applications will assist the farmer in taking his daily management decisions and generate early warnings when something is going wrong in the production process.

The PLF concept is rather new in the European pig industry, but today, early adopters are starting to use it. Some PLF technologies such as pig cough monitors, automatic weighing devices, and camera systems are commercially available now, but the business intelligence software is still under development and under constant improvement. A big European-funded Project (EU-PLF) was started up in 2012 to prove the added value of PLF in 20 commercial farms in Europe. Data collection has been done over 20 fattening periods, and early warning tools for farmers have been developed. Also, automated welfare assessment based on electronic sensor output has been developed.

The output of the sensors (e.g., activity measures with a camera or sound measures with a microphone) is related to animal-based welfare and health indicators such as aggression or respiratory diseases. When sensor signals start to deviate from their expected values, alerts are given to the farmer. In this way the farmer can take an immediate action before the detected change in animal response negatively affects the production performance. These actions range from solving technical problems such as a blocked feeding line, adjusting control settings in the climate and feed controller, or starting a “soft” preventive medical treatment in the animals. In most cases, a preventive medical treatment prevents the further spreading of respiratory diseases in the pen, and the use of antibiotics can be reduced or even precluded.
Most of the available PLF behavior sensors are not monitoring the individual pigs, but rather, certain areas in the house. Despite an increasing trend for bigger (100+) groups, most pigs in Europe are kept in a compartment with smaller groups (8–25 pigs per pen). Most sensor output is related to a group of pigs at pen or compartment level. The systems generate more reliable outputs than a human observer because they are available 24 h/d and 7 d/wk.

The most commonly used PLF sensors for pigs are water meters, animal weight sensors, feed supply monitors, camera systems to measure animal activity and distribution, and sound monitoring for respiratory diseases. In the commercialization of the PLF systems, a stepwise approach is used, starting with feed intake, water intake, and weight. The price of the commercial sensors is no more than a few thousand euros per shed.

Due to the increasing demand for meat, the scale of the farms will grow. Farmers will serve multiple houses (at different locations) and will have less time to care for each individual animal. That means the use of automated monitoring systems presenting up-to-date information to the farm manager will be the only viable option to guarantee the health, welfare, and optimal performance of the animals. Precision farming technologies will provide the license to produce and give an answer to the increasing demand for cheap and healthy food products.

Once the sector starts to understand how valuable the information they produce is, not only to them, but also to other stakeholders such as feeding companies, veterinarians, breeding companies, consultants, processing plants, retailers, and also the consumers, the desire for data will increase exponentially, resulting in a completely different approach to meat production. If we consider what has happened in virtually every other industry over the last 20 yr, this information-based approach becomes inevitable.

**Identification of Animals**

The identification of individual animals in the pen will enable the livestock managers once again to treat their animals as individuals rather than a herd or flock. The individual care of animals could facilitate the provision of individually tailored diets and environmental control. Both have an enormous effect, and hence, potential on the improvement of productivity and welfare. Individual identification and monitoring of animals is an important step toward enhancing the traceability of livestock products through the supply chain (Naas, 2002). Individual animal identification can technically done by several methods, which are listed in Figure 1.

**Water Intake Monitoring**

Water consumption monitoring is one of the simplest and most effective tools that a farmer can use to monitor the performance of his animals. Water meters provide accurate information about water usage of the animals and create the possibility to monitor performance of the animals in a simple and effective way (Figure 2). Water intake can be monitored on shed level, compartment level, pen level, or even individual animal level. Differences between expected and measured water consumption are immediately visible, enabling a response before any abnormalities can affect the welfare or health of the animals. A deviation in the water:feed ration during the day is usually an early sign for health problems (Adriaens et al., 2014).

Moreover, the system warns when crossing the minimum or maximum flow, detecting any blockings or leakages at a very early stage. Water registration also helps to apply adequate vaccination strategies. Vaccines are usually distributed over drinking water, and therefore, it is important for farmers to know exactly when the water consumption is at the highest level during the day.

**Automated Weight Detection**

The key in fattening pigs is to optimize the growth performance of the pigs. Therefore, an accurate and non-intrusive method for weighing pigs on a regular basis without the need for labor input is a relevant tool for pig producers. Several research teams attempted to develop a pig weighing system based on image analysis, including scientific teams in the UK (Schofield, 1990; Schofield et al., 1999), Denmark (Brandl and Jorgensen, 1996), the USA (Wang et al., 2008), Belgium (Kashiha et al., 2014a), and Australia (Kollis et al., 2007). The importance of image analysis in the agricultural sector increases day by day, especially within the livestock industries due to the ability of machine vision applications to capture im-
important information related to the competitiveness of the farm, such as the health, growth efficiency, weight, and carcass composition of animals (Banhazi and Black, 2009; Doeschl-Wilson et al., 2005; Whittmore and Schofield, 2000). More recently, several commercial systems (Weight-Detect by PLF-Agritech, eYeScan by Fancom BV, Pigwei by Ymaging, OptiScan, GroStat, and WUGGL) have been introduced. The principle of the automated weight detection by video image analyses is, in theory, quite simple, but in practice, more challenging. First, the pig body needs to be segmented from the pen background. Second, pig body characteristics are determined on the segmented pig body, and they are used to calculate pig-related features such as body area, body length, and width etc. In the last step, these features will be related to the body weight of the animal by a mathematical model such as a linear regression model. Current commercial systems achieve an accuracy of less than 1.5 kg.

Figure 3 shows the output of the eYeScan system, which obtains the pig’s weight using 3D video image recognition. The system includes a hardware module with special image processing software to which a maximum of four cameras can be connected. The analysis software delivered with the system enables continuous growth monitoring of a group of animals.

Monitoring Pig Behavior with eYeNamic

eYeNamic is a system that is used both in pig and poultry farms (Figure 4). The camera-based system is positioned in top-down perspective and generates a visualization of the floor area. The analysis software translates the acquired images into indexes of distribution and activity. These indexes are a measure of the animal’s position and movement, and thus, of animal behavior. Image processing technology and mathematical modeling lead to more frequent monitoring of health- and welfare-related responses of livestock animals (Kashiha et al., 2013).

Changes in activity can be caused by abnormal behavior due to aggression (Viazzi et al., 2014), lameness, or other locomotion problems (Kashiha et al., 2014b; Peña Fernández et al., 2016).

Pig Cough Monitoring

Respiratory problems are very common in pig herds, causing significant economic losses. Early treatment of problems is crucial for reducing the economic losses and the amount of antibiotics used in the process. Early warning for the problem allows earlier treatment, causing fewer animals to be affected and taking less time to cure the animals. The Pig Monitor is a tool for the automated and continuous monitoring of coughs in a pig herd (compartment level). The Pig Cough Monitor can be used as an early warning tool, and it also demonstrates the effects of treatment and preventive measures (e.g., difference between different vaccines) (Finger et al., 2014; Genzow et al., 2014).

Early Warnings with Precision Livestock Farming Systems

The development of early-warning software allows the automated analysis of PLF data, which will lead the farmer automatically toward the problem when it occurs (Figure 5). The farmer will not have to scavenge through all data to perform an analysis because it is being done by the software. By analyzing the data from PLF systems with a predictive model, deviations between expected and measured values can be automatically detected. The added value is created by the algorithms that translate the output of the sensors to useful information to the farmer. It was proven that the measures of a change in animal behavior (monitored with a camera) or respiratory disease (measured with a microphone) are relevant performance indicators. The changes mainly occur as results of technical failures in feed, water or environmental control, animal sickness, or after inappropriate management decisions, such as sudden changes in light schemes.

The alerts created by changes in animal behavior can be reported in dashboards on PC or mobile devices. Farmers are directly guided to the location of the problem, thus saving time and avoiding production losses. As most farmers today can only achieve about 70% of the genetic potential of their flocks, we think that the early warning functionality can result in a 10% higher performance. This will allow a management by exception protocol for the farmer. This procedure has been scientifically described and published (Kashiha et al., 2013).

An example of the early-warning protocol is presented in Figure 6 for the variable water intake of pigs. The early-warning protocol predicts the expected water intake based on historical data. When the measured data lie outside the range of the expected behavior (red color), a warning is raised. This warning can be hard, meaning that a text message or email is sent to the farmer to take immediate action. The warning can also be soft,
meaning that a notification will be made of this alarm in a notification list. Farmers can access this list when they want, preferably once a day to address all alarm situations on their farms. The type of action will depend on the type of warning and on the variable that is causing the alarm.

A similar early-warning protocol was developed for the pig cough monitor to generate early warnings of respiratory diseases to the farmer. The underlying early warning algorithm is however different, and is generated by applying the principles of statistical process control (SPC) on the pig cough data (Oakland, 2003). The procedure to generate the alarms was based on comparing the actual cough data points with control limits based on the running mean and corresponding standard deviations. Alerts were then generated in function of the data points crossing the control limit lines for sufficiently high levels of pig coughing (Berckmans et al., 2015). This procedure is scientifically described in the publication of Hemeryck et al. (unpublished) that has been submitted for publication in Computers and Electronics in Agriculture.

Automated Welfare Assessment

There is a growing interest in the automated monitoring of pig welfare. Animal welfare is multifactorial and is, therefore, hard to measure. The European research project Welfare Quality has developed a welfare quality assessment protocol. This protocol is, as many animal welfare projects, based on the Five Freedoms defined by the Brambell Commission (1965)

- Freedom from hunger and thirst
The welfare criteria and principles used by the Welfare Quality assessment protocol are:

- Freedom from discomfort
- Freedom from pain, injury, or disease
- Freedom to express normal behavior
- Freedom from fear and distress

The welfare criteria and principles used by the Welfare Quality assessment protocol are:

- Good Feeding: Absence of prolonged hunger, Absence of prolonged thirst
- Good Housing: Comfort around resting, Thermal comfort, Ease of movement, Absence of injuries, Absence of disease, Absence of pain induced by management procedures
- Good Health: Expression of social behaviors, Expression of other behaviors, Good human-animal relationship, Positive emotional state
- Appropriate Behavior: Absence of injuries, Absence of disease

This welfare assessment is performed by a trained expert. After a visit to a farm (approximately 3 h per shed), this expert is capable of calculating an objective welfare score per welfare principle for that particular farm. This is a time-consuming and complicated process and, moreover, a snapshot of the animals welfare state.

Precision livestock farming offers possibilities to automate the welfare assessment. Many PLF sensors already exist today to automate the assessment of several welfare criteria, such hunger, thirst, and thermal comfort. Other welfare criteria can be deduced indirectly from the automated PLF measurements. Camera and sound systems make it possible to assess bird behavior objectively, so research is now focusing on the objective assessment of welfare criteria based on PLF measures. The ultimate goal should be the development of a dashboard based on the welfare principles and welfare criteria of the welfare quality assessment protocol shown in Figure 7. In this way, animal welfare is objectively assessed 24/7 and without the need of an expert.

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Source: Temple Grandin

Good Feeding

Good Housing

Good Health

Appropriate Behavior

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