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Research Paper

Evaluation and characterisation of Passive Infrared Detectors to monitor pig activities in an environmental research building

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In confined feeding operations, animal activity can affect environmental variables such as indoor gas and dust concentrations, which can have negative impact on animal health and welfare. Therefore, monitoring animal activities is important in research into the environment of animal rearing. In this study, low-cost Passive Infrared Detector (PID) motion sensors were studied to monitor pig activities in the Swine Environmental Research Building, Purdue University, USA. Special functions were programmed into custom-developed data acquisition software to process the sensor analogue output signals and provide real-time, continuous, and quantitative data, which reflected behaviour-related pig activities. Signals from the PID sensors were averaged at different time intervals for data interpretation. Data using the PID sensors demonstrated substantial differences in activity magnitudes of pigs between day and night, which confirmed diurnal patterns of pig behaviours. Short-time disturbance by operational work in the rooms could cause prolonged excitement and activities of the pigs. In addition, the study revealed that pigs were active at different times of the day as they grew up. Pigs were most active between 30 and 100 post-weaning days. Based on the results of this study, PID sensors can be used to assist in monitoring pig activities in livestock production and research into animal behaviours and welfare.

1. Introduction

The environment in which an animal is reared can affect its activities that have been defined as animal movements (Pedersen & Pedersen, 1995). Animal health and other status (e.g., disease or other stressors) is often related to overt activity and behavioural changes. However, animal activities can also affect the rearing environment and the emission of airborne pollutants from animal feeding operations. It was found that the morning urination activities of pigs were followed by increased ammonia (NH_3) concentrations in pig rooms (Aarnink, Keen, Metz, Speelman, & Verstegen, 1995) and the increased evening activities of cattle in a feedlot were

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related to peak concentrations of particulate matter (McGinn et al., 2010). Therefore, better understanding of animal activities can benefit research into the behaviour, health, and productivity of animals as well as environmental pollution.

Animal activities have been studied using methods such as direct visual observations (e.g., Botermans & Andersson, 1995), video-aided observations (e.g., Botermans & Svendsen, 2000), and accelerometery (e.g., Shepard et al., 2008). However, different technologies have their own advantages and disadvantages. A simple method using Passive Infrared Detector (PID) motion sensors was first reported in 1994 to monitor domestic animal activities (Pedersen & Takai, 1994). The PID motion sensors are commercially available and are widely used for security alarms and device controls. These motion sensors work on the principle that some crystals exhibit a temperature-dependent electric field, which can be measured when the crystals are supplied with electrodes. By using a specially designed lens, an object with an infrared radiation source moving in front of the sensor can activate a pyroelectric detector within the sensor thereby detecting the movement of the object (Pedersen & Pedersen, 1995).

The effectiveness of PID sensors for animal movement monitoring was studied in the U.K. by Pedersen and Pedersen (1995) with an artificial pig. The authors found that the sensor signal output was a function of the temperature difference between the moving body and the floor, and the velocity of the moving body. Since then, there have been applications of this technique in different studies in Europe for monitoring pigs (e.g., Blanes & Pedersen, 2005; Puppe, Schon, & Wendland, 1999), layer hens (Von Wachenfelt, Pedersen, & Gustafsson, 2001), broiler chickens (Nielsen, 2003), and dairy (Ngwabie, Jeppsson, Gustafsson, & Nimmermark, 2011). The technique has even been used with free-ranging wild animals (Langbein, Scheibe, Eichhorn, Lindner, & Streich, 1996).

Application of this technique in USA started at the beginning of the 2000s (Heber, Tao, Ni, Lim, & Schmidt, 2005). In the National Air Emission Monitoring Study, in which eight universities in USA participated (Heber et al., 2008), PIDs were used as the standard sensor (Ramirez, 2006) that was required at 38 commercial animal buildings to continuously monitor animal activity for two years during the study.

Use of the PID technique has contributed to obtaining new insights into animal behaviours and environment. For example, Jeppsson (2002) found that diurnal PID sensor signal variations were correlated to NH_3 emissions from a pig building and similar findings were reported by other researchers (e.g., Heber et al., 2005).

A comparison study (Nielsen, 2003) also demonstrated the advantages of using PID sensors rather than video methods. The pixel-change data in video appeared to be less accurate than the PID for detecting behavioural changes of grouped birds following bursts of activity, and the processing of data from video was more time consuming than the PID technique.

The output of PID sensors is a voltage signal that requires data acquisition and signal processing using hardware and software before meaningful data can be saved in a computer and used for animal behaviour and activity analysis. In the early application of this method, Pedersen and Pedersen (1995) developed purpose-built stand-alone data acquisition hardware that included an amplifier, a filter, a rectifier, and a buffer.

Two more innovative systems were later developed to facilitate the use of PID. A small solar powered activity-data-logger (ADL), that could store information for up to 80 days, was developed for recording the presence and movements of free-ranging animals. Locomotor activity was detected with a PID and at fixed intervals the signals picked up by the PID were condensed automatically and stored within the ADL (Langbein et al., 1996). Another system in which the sensors were linked on-line via a digital I/O (rather than analogue I/O) interface to a personal computer provided with self-developed analysis software based on LabVIEW (Puppe et al., 1999), but no details about the system were provided in the research paper.

With the rapid development of computer technology, and availability of improved data acquisition hardware, there are new possibilities for developing improved systems to reduce their cost and make them more reliable and user-friendly. Moreover, in animal research and production, activity is usually only one of many important monitoring variables that are available. Others include temperature, humidity, ventilation, and pollutant gas concentrations. Integration of these measurements into a single and compact system can not only help improve data quality, but also save time in post-measurement data processing and facilitate data interpretation.

The PID sensor technology was applied and integrated into a data acquisition and control system to monitor pig activities in the Swine Environmental Research Building, Purdue University. The objectives of this paper are to evaluate and characterise the technology of using the PID sensors by presenting methodologies and providing results of signal processing and data interpretation from the pig activity monitoring in the research building.

2. Materials and methods

2.1. *Research building*

The research building is located at the Purdue University's Animal Sciences Research and Education Center, in West Lafayette, IN, USA. The facility was built in 2004 and has 12 pig rooms on north and south sides of the building (Fig. 1).

There are two rows of pens and two isolated 1.8-m deep manure pits under the slatted concrete floor in each room, which measures 11.0 m × 6.1 m × 2.7 m (L × W × H) with a capacity of housing 120 nursery or 60 finishing pigs. The number of pens in each row can be changed as required but is usually from 3 to 6 pens.

The rooms are under negative-pressure ventilation. There are two wall exhaust fans and two pit exhaust fans providing ventilation in each room. One wall fan (Model V4E35, Multifan, Bloomington, IL, USA) is a single-speed, 180-W (at 240 VAC) fan that has a 356-mm diameter. Another wall fan (Model V4E50, Multifan) is also a single-speed, but 430-W (at 240 VAC) fan that has a 508-mm diameter. The two pit fans are variable-speed, 254-mm diameter tube-mounting fans (Model P4E30, Multifan). Fresh air is supplied to the rooms from baffled ceiling inlets and the building hallway. In cold weather, air is pre-heated in the hallway and then further heated by