Evaluation and characterisation of passive infrared detectors to
monitor pig activities in an environmental research building

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Abstract

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.

Keywords: animal activity; animal behaviour; data acquisition; motion sensor; PID; pig production.

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 (NH₃) concentrations in pig rooms (Aarnink, Keen, Metz, Speelman, & Verstegen, 1995) and the increased evening activities of cattle in a feedlot were related to peak concentrations of particulate matter (McGinn et al., 2010). Therefore, better understanding of animal activities can benefit research on 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 accelerometry (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). PID 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 the 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 development 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.

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2. Materials and methods

2.1. Research building

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

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

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108 Fig. 1. Cross-sectional east side view of the Swine Environmental Research Building.

109 The rooms are under negative-pressure ventilation. There are two wall exhaust fans and
 110 two pit exhaust fans providing ventilation in each room. One wall fan (Model V4E35, Multifan,
 111 Bloomington, IL, USA) is a single-speed, 180-W (at 240 VAC) fan that has a 356-mm diameter.
 112 Another wall fan (Model V4E50, Multifan) is also a single-speed, but 430-W (at 240 VAC) fan
 113 that has a 508-mm diameter. The two pit fans are variable-speed, 254-mm diameter tube-
 114 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 individual heaters in each room, where the indoor environment is individually controlled.

A state-of-the-art environmental monitoring system has been permanently installed in the building for all the 12 pig rooms. Operations of all ventilation fans are monitored individually and continuously. Moreover, the system also measures and records temperature, relative humidity, pig activity, room static pressure, and concentrations of gases (including NH_3 , hydrogen sulphide (H_2S), and greenhouse gases). A more detailed description of the building and its monitoring system was provided by Ni et al. (2016).

2.2. Sensor and sensor installation

Although there are many types of commercial PID sensors available, most of them only provide digital outputs that can be used for on/off switch controls. The PID sensor (Model SRN-2000 Detector, Visonic Inc., Bloomfield, CT, USA) selected in this study provides both digital and analogue outputs. It has maximum surface detection coverage of 18 m (L) $\times$ 18 m (W) at a 90° horizontal angle.

Twelve PID sensors were mounted on the end-walls in 12 pig rooms at 2.2 m above the floor and tilted downward at 15° to detect the movements of infrared radiation from the pigs (Fig. 2). The “T.P.” terminal inside the sensor was connected to a data acquisition analogue input channel and the “12 V–” and “12 V+” terminals were connected to a 12-volt DC power supply.

After signal processing, the values of the sensor analogue output signals can be proportional to the temperature differences between pigs and the background, as well as the pig motion strengths. This allows obtaining continuous and quantitative data that reflect the pig activities (Pedersen & Pedersen, 1995).

Fig. 3. The PID sensor and its mounting position in a pig room. Left, open-cover view of the sensor; Middle, the sensor with the lens and front cover on; Right top, side view of the room; Right bottom, floor plan of the room.

2.3. Data acquisition and signal processing

An on-site computer system (Ni & Heber, 2010), including custom-developed software AirDAC which was programmed in LabVIEW, was used for data acquisition and signal processing. All signals were acquired at 1 Hz. The system integrated data acquisition for all on-line hardware, which includes several types of measurement devices (sensors and gas analysers). To satisfy this requirement of multiple types of devices, two generalised equations (Fig. 3 top) were developed to convert analogue, digital, thermocouple, and counter signals from all the measurement devices except for PID sensors, and make the necessary corrections. The first equation converts electric signals in voltage, or current, into measurement values in engineering units, which are defined by the measurement devices. The conversion is based on the signal range and measurement range that are configured or set in the measurement device. The second equation is a linear model for real-time data correction based on calibration results of the device.

In the equations shown in Fig. 4 top, X_i is the converted i^{th} measurement value, unit defined by the measurement device; S_i is the device output i^{th} signal received by AirDAC, unit in VDC,

156 A , or defined by the device; S_H and S_L are the configured device signal range at high end and low
 157 end, respectively, same unit as S_i ; R_H and R_L are the configured device measurement range at
 158 high end and low end, respectively, unit defined by the device; Y_i is the corrected measurement
 159 data, unit defined by the device; A is slope; and B is intercept.

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162 Fig. 4. Equations in LabVIEW programed in AirDAC for signal conversion and data correction.

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Top, for non-PID measurement devices; Bottom, for the PID sensors.

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However, signals from the PID sensors, although in analogue voltage, are unique compared with other devices and require special processing. This is because the PID sensor signals contain an offset voltage, which is 2 V-DC. The strengths of motions detected by the sensors are proportional to the analogue output $X_i = \text{offset} \pm S_i$. Therefore, equations in (Fig. 3 bottom) were developed to take care of the offset by using a special S_L and calculating the absolute value of X_i for the PID sensors. To use these equations for the PID sensors, signal conversion setting is $S_L = \text{offset} = 2$, $S_H = \text{offset} + 1 = 3$, $R_H = 1$, and $R_L = 0$. The A and B in the second equation were entered based on the correction needs of individual PID sensor. If no real-time correction was

needed, then $A = 1$ and $B = 0$.

A user-friendly interface was developed to accept and save parameters S_H , S_L , R_H , R_L , A , and B at run-time for each individual device in AirDAC (Ni & Heber, 2010). Data Y_i calculated from signals at 1 Hz were displayed real-time in the computer. They are also averaged over 15-sec and 1-min intervals and saved in two separated data files. The 1-min data files were automatically pre-processed every day; and the results and graphs were delivered to researchers via emails using AirDAC.

2.4. Evaluation of the sensors for pig activities at different ages and in different numbers

Signals from the PID sensors were compared in this study among six rooms (Room 1 to Room 6, or R1 to R6) when pigs of different growth stages (nursery versus finishing) and in different numbers (120, 60, 47, and 17 pigs) were housed in these rooms. High frequency data at 1 Hz were taken using computer screen shots from real-time display during the daytime (from about 16:00 to 18:00) and after midnight (from 00:00 to 02:00, 8 h following the daytime screen shot).

Tests were also conducted to verify and demonstrate the impact of in-room production operation on pig activities. This test was realised by having a researcher walk into the room along the walkway between the two rows of pens for one minute. Real-time PID sensor responses before and after the test were recorded and compared.

2.5. Evaluation of the sensors during an entire pig growth cycle

A data set from a recently completed research project that included an entire pig cycle in the building was used in this study to characterise the relationship between the PID sensor signals and pig behaviours. In this pig cycle, nursery piglets, weighed between 4.5 and 13.0 kg each, entered into R1 to R6 on February 25, 2015, and into R7 to R12 on March 4, 2015. There

were 60 mixed-sex pigs in each room under a dietary crude protein study. All pigs were fed *ad libitum* (Liu, Ni, Radcliffe, & Vonderohe, 2017; Vonderohe et al., 2016).

2.6. Data processing

Post-measurement data processing from all environmental monitoring variables was performed using custom software CAPECAB (Fibre Recovery Systems Inc., Calgary, AB, Canada) (Cortus et al., 2010). Raw data first went through validation. Plotted data were visually inspected and compared with experimental notes. Corrections were made when necessary based on experimental conditions and sensor signal qualities. Abnormal data due to system maintenance or other reasons were invalidated. A scale factor or a linear equation was applied when necessary to filter out noises from the PID sensor signals. Statistical data comparison was performed using t-Test and ANOVA.

Data from 11 of the 12 rooms were used because the valid data from R1 did not cover most of the pig cycle. The valid PID sensor data were averaged every 30 min and every day to investigate the diurnal and pig cycle patterns, respectively. Data were also divided by months to study age-related pig activities.

3. Results and discussion

3.1. Monitoring system performance

By taking the absolute value after subtracting the offset voltage from the sensor output, the PID sensor signal processing was demonstrated as being a simple and effective method. Multiple sensor output signals shown in 2-h history graphs at 1 Hz (Fig. 5) has offered a convenient real-time monitoring using the on-site computer or remotely using commercial remote administration software such as TeamViewer (TeamViewer GmbH, Utingen, Germany). The example computer screen shots in Fig. 5 demonstrate that the PID sensors in the pig rooms were able to

detect the following pig activity variations:

- Day (from 15:57 to 17:57 in the left figures) and night (from 0:00 to 02:00 in the right figures);
- Pigs at different growth stages (nursery pigs in R1 and R2 versus finishing pigs in R3 to R6);
- Finishing pigs in different numbers (full rooms with 60 pigs in R3 and R4 each room, and partially-filled rooms with 47 pigs in R5 and 17 pigs in R6);
- Normal activities and induced excitement and movement by the entrance of a researcher (arrow indications in the left figures).

Fig. 5. An example of real-time activity signal display in AirDAC at 1 Hz in the afternoon (left) and after midnight (right) in Rooms 1 to 6 (from top to bottom). Rooms 1 and 2 housed 120 nursery pigs each; R3 and R4 had 60 finishing pigs each; R5 and R6 had 47 and 17 finishing pigs, respectively. Arrows indicate the time when a researcher entered the room for a 1-min walk.

The PID sensors had short response time of < 1 sec. Single and narrow signal peaks indicated short time and individual pig activities. Signal spikes with higher density could usually be related to a combination of more pigs in movement, longer movement time, and higher movement strengths.

3.2. Processing and interpretation of data over different average intervals

Although a large portion of the sensor signal outputs seems to be saturated at 2 V in R1 and R2 during daytime in Fig. 5 (left), when the 1 Hz voltage signals are processed into 15-sec average data, information display is greatly improved (Fig. 5). Clear activity strength variations can be seen in the 15-sec data although not shown in the 1 Hz signal history display. Comparison of sensor signal outputs 5 min before and 5 min after the walk-in showed significant ($P < 0.05$) differences in all six rooms, demonstrating that the sensors effectively detected the pig activity changes (Table 1). The excited pig activities caused by the 1-min walk-in of the researcher as shown in Fig. 4 (left) lasted from about 15 min to more than one hour.

Fig. 6. Processed 15-sec mean pig activity data after averaging the signals shown in Fig. 4 (left).

Arrows indicate the time when a researcher entered the room for a 1-min walk.

Arithmetic means of the PID sensor data were easily obtained over different time durations (e.g., 15-sec and 1-min real-time in AirDAC; 30-min, 1-h, and daily post-measurement in CAPECAB) while preserving essential quantitative information from the sensor signals. This allows better understanding of the pig activities for different data interpretation purposes.

Table 1. Comparison of pig activities before and after the walk-in test using 15-sec means of sensor signal outputs.

	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
1-min walk-in start time, hh:mm	17:31	17:39	17:41	17:43	17:45	17:48
5-min mean before walk-in, V	0.571	0.944	0.124	0.592	0.226	0.257
5-min mean after walk-in, V	1.053	1.419	0.653	0.761	0.607	0.712
t-Test P value	0.000	0.000	0.000	0.015	0.000	0.001

3.3. Characteristics of diurnal pig activities

The 30-min mean PID sensor signals revealed clear diurnal patterns of the pig activities in the 11 rooms (Fig. 7). Like all non-nocturnal animals, pigs in the building were more active during daytime. Their lowest activity hours were between 03:00 to 04:00 for the entire growth cycle. The highest PID sensor outputs in a day were either in the morning between 07:00 and 09:00 or in the afternoon between 13:00 and 15:00, depending on the ages of the pigs. The PID sensor signal strengths decreased steadily into the night following the afternoon peak.

During the first month of the pig cycle, there were multiple peaks of PID sensor outputs in a day. This pattern changed to a two-peak pattern started from the second month of pig growth cycle. The second and third months of the growing cycle was the most active period.

One-peak and two-peak activity patterns were reported by Heber et al. (2005) in two commercial finishing barns for three groups of pigs and were related to seasons. Botermans and Svendsen (2000) also reported two or more activity peaks for growing and finishing pigs. Two of the groups generated a major activity peak in the morning and a minor peak in late afternoon. These observations were similar to, but not exactly the same as, those in this study. Results of statistical t-Test of the averaged 30-min mean PID sensor outputs during different post-weaning days, as shown in Fig. 6, revealed that the diurnal pig activity patterns were all different ($P < 0.05$) except between days 1–30 and days 121–147 ($P = 0.124$), demonstrating the similarity and differences in overall 30-min patterns of diurnal pig activities.

Fig. 7. Processed 30-min mean PID sensor signal patterns during different post-weaning days and the entire pig growth cycle in 11 rooms (R2 to R12).

3.4. Characteristics of pig activities at different ages

Daily mean PID sensor data showed that when the post-weaning piglets initially entered into the rooms at the beginning of the entire pig cycle research, they were extremely excited in the new living environment, generating more activity signals (Fig. 8). The strengths of the signals decreased within less than a week to almost the lowest levels of the entire pig cycle. This could be linked to the behaviours associated with the adaptation process of the piglets to a new living environment. An obvious increase in activities was shown thereafter until about 50 to 60 post-weaning days. The highest pig activities were detected roughly between post-weaning days 30 and 100, followed by decreasing activities during the finisher phase.

The PID sensor signal outputs in all 11 rooms demonstrated very similar arch-shaped curves for the entire pig cycle. Lower activity signals during the first month, except for the first

week, could be related to the smaller pigs that covered much less floor area compared with larger pigs. Observations in the rooms confirmed that adult pigs close to the end of the cycle tended to lie on the floor and sleep more hours every day. These pig behaviours also agreed with the results from direct visual observations reported by Botermans and Andersson (1995). This confirmed the PID sensor outputs and could support the validation of the PID sensor technique in monitoring pig activities.

Fig. 8. Processed daily mean PID sensor data showing variations of pig activities during the entire growth cycle in 11 rooms.

Variations in signal magnitudes among different rooms can also be seen in Fig. 7. These variations could be related to a couple of reasons. The first possible reason could be the variations among the sensors, interferences to sensor signals, and obstruction of sensor lens by dusts, etc. Calibration of the sensors using the similar method as developed by Pedersen and Pedersen (1995), and periodic check of the sensor status in the research could help to minimise the introduction of these possible errors.

The second possible reason could be the variations of pig activities among the rooms. Figure 4 clearly demonstrates these variations even between two rooms with the same, or similar, numbers of pigs at the same growth ages. Analysis of daily mean data shown in Fig. 7 with ANOVA, also showed significant differences among individual rooms with the same dietary treatment or as controls ($P < 0.01$) as well as among the three groups of rooms (two treated and one control) ($P < 0.01$). It was often observed that a pig in the confined building would easily be agitated by the excited or aggressive behaviour of another pig. When there were one or more pigs with unusual behaviours in a room, this could affect activities of many other pigs in the same room.

Moreover, workers entering the room to perform routine operations could also excite the pigs and cause variations of their activities. These excited pig behaviours lasted from 15 min to more than 1 h before they decreased, as demonstrated in Fig. 5 (left). Therefore, if the errors of and differences among the PID sensors can be eliminated or corrected, the PID technique could be a simple and useful approach to monitor animal activities and behaviours in pig research and production.

3.5. Cost of materials

The major components of the PID sensor technique included the PID sensors and the data acquisition hardware. The PID sensors initially installed in the pig building cost about US \$40 each. The PID sensors were found to have a reasonably long lifetime although they were installed in pig rooms where there was a relatively harsh environment with the presence of corrosive gases, such as H_2S and NH_3 . During the 12 years of use in the research building, only two sensors have been replaced.

For the data acquisition hardware, a single-ended analogue channel was used for each PID

sensor in this study. There are many choices of data acquisition hardware, of which the cost can vary considerably. The system in this study has used the 16-bit FieldPoint FP-AI-112 modules (National Instruments Co., Austin, TX, USA) that were installed more than a decade ago and initially cost about US \$50 per analogue input channel. This cost included a controller module (FP-2000, National Instruments Co.) that was shared between the multiple analogue input, thermocouple, and digital output modules. However, the sensors can work well at lower resolution (e.g., 14-bit or 12-bit) using analogue input hardware that is a lot cheaper. Some lower cost options exist for these types of analogue input hardware. One such option that was tested was the USB 12-bit data acquisition devices (Measurement Computing Co., Norton, MA, USA) that cost less than US \$15 a channel.

Other material-related costs are the 12 V-DC power supplies and the sensor connection cables. Whereas a power supply can be shared with multiple sensors, each of which only consumes < 0.5 W power, and is not expensive, the cables can add in different amount of costs, depending on the types of cables selected and distances of connections between the sensors and the data acquisition system.

3.6. Sensor maintenance

Pig houses usually have high dust concentrations. Accumulation of dust was found to lower the sensitivities of the PID sensors in our previous research in commercial layer hen houses where higher particulate matter concentrations were reported (Ni et al., 2012). However, dust was not found a major problem in this study, partly because of relatively lower dust concentrations compared with poultry houses and partly because the PID sensors were installed with a downward tilt angle of 15° (Fig. 3) that reduced possible dust accumulation on the sensor lens.

However, periodic maintenance was found necessary. The PID sensors were usually disconnected from the cables and uninstalled from the walls during power washing of the rooms between cycles of pigs in the research building. They were checked and cleaned before being re-installed.

3.7. Assessment of the PID sensor technique

Animal activities are usually expressed descriptively. For example, Botermans and Svendsen (2000) recorded pig behaviours using a time-lapse video recorder. The number of pigs eating, standing, sitting, and lying was noted from the tapes at 5 min intervals with fuzzy quantities.

Compared with the method of video recording plus manual image interpretation, the PID sensor technique cannot distinguish different pig activities. Moreover, the PID sensor signal outputs are dependent on distances of the pigs. Using only a single PID sensor in each room, as in this study, left some uncovered dead zones (Fig. 2).

However, PID sensors can provide a general but objective quantification of the pig activities. They enable monitoring of activity patterns as well as changes in activity levels of animals over time, even during darkness (Nielsen, Kjaer, & Friggens, 2004). Their continuous single-voltage output allows direct and instantaneous inspection of general animal activities real-time. Easy data averaging and statistical testing applicable to the signals is also very useful for studying animal behaviours at different time intervals. Most importantly, they have much lower cost of usage, in terms of both materials and time, compared with video-aided techniques. The low costs allow multiple-sensor application that can improve coverage of the pig rearing area or monitor particular pigs. Also, previous research has shown that PID sensors can be used to monitor individually housed sows for their behaviours, e.g., estrus (Freson, Godrie, Bos,

Jourquin, & Geers, 1998). Therefore, PID sensors can be useful for animal research and production.

4. Conclusions

The following conclusions were drawn in this study:

1. The PID sensor signal processing used in this study has been shown to be a simple and effective method.
2. Real-time and high frequency displays of the PID sensor signals provided a convenient way to visually inspect pig activities on-site and remotely.
3. Studies using the PID sensors revealed that higher density of signal spikes could usually be related to a combination of more active pigs, longer movement time, higher activity strengths, and number of pigs.
4. Variations of pig activities exist among different rooms, even with the same numbers of pigs at the same growth ages.
5. Pig activity patterns varied diurnally and at different growth ages. The highest activity levels were detected for pigs between approximately 30 and 100 days post-weaning and this was followed by decreased activity.
6. Excited pig behaviour, caused by a researcher walking-in to the rearing room, could last from around 15 min to more than one hour.
7. The low-cost PID technique used in the experiments could be a useful approach both in animal environment research and animal production. This study supported the validation of this technique in investigating pig activities and behaviours.

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