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The Automatic Monitoring of Pigs Water Use by Cameras

ABSTRACT

Every year over 59 billion animals are slaughtered for worldwide food production. The increasing demand for animal products has made mass animal breeding more important than ever. Satisfying the needs of the market, farmers will have to use automatic tools to monitor the welfare and health of their animals since manual monitoring is expensive and time consuming. Literature has shown that water use of pigs relates to important variables such as inside temperature, food intake, food conversion, growth rate and health condition. So, water use might be an interesting indicator for automatic monitoring pigs' health or productivity status. Therefore, we tried to find a cheap and elegant way to monitor continuous water use in a group of pigs in a farm pen. This study comprised four groups of piglets, each group of ten animals in a pen. On average, in the beginning of experiments pigs had a weight of 27 kilograms and in the end they gained weight up to 40 kilograms. Using a water-meter for each pen, water use rate was measured and monitored minutely. The pig house was also equipped with Charge-coupled device (CCD) cameras. Each pen was monitored for 13 days using a camera which was installed above the pen to generate top-view images. There was a water outlet in the corner of each pen. Employing image processing algorithms, drink nipple visits were monitored automatically. Using data of a performed experiment comprising three weeks of data recordings, the relationship between water use and drink nipple visits was investigated. Results showed that by developing a data-based dynamic model of the visits to the drink nipple observed in videos, half-hourly water use could be estimated with an accuracy of 92 per cent.

Key words: Pig welfare monitoring; water use monitoring; drink nipple visits; pig barn; transfer function modelling

1. INTRODUCTION

Technology makes it possible for producers to increase the number of animals in their flock or herd. While these systems allow a more efficient labour, the reduced ratio of farmers to animals results in welfare problems (HSUS, 2010). One of the essential components of welfare in animal husbandry is providing adequate food and water (Botreau *et al.*, 2007). On the other hand, a substantial amount of man-hour is required to guarantee animals having efficient access to water and food. To meet the demands of the market while providing enough care to all animals, farmers might use automatic tools to monitor welfare and health of their animals.

Water is an essential need for pigs and inadequate access to it may result in reduced feed intake, reduced production and increased health problems (Gonyou, 1996). In addition, water use[1] is a good indicator of other parameters in pig husbandry. For example, feed and water use are closely related. The low level of eating may relate to insufficient drinking activity, as solid feed intake must be accompanied by water intake (Dybkjaer *et al.*, 2006). Monitoring of the drinking behaviour of young pigs, has proved to be a useful tool in detection of diseases and other production related problems too. For instance, it is known that by on-line monitoring of water consumption of young pigs, an outbreak of a disease (diarrhea) can be detected approximately one day before physical signs are seen on the pigs (Madsen and Kristensen, 2005b) and the stops in the automatic feeders can be detected since these cause huge deviations in the level of water consumption (Madsen and Kristensen, 2005b). Therefore, it is beneficial to develop an automated monitor of water use by pigs in a pen.

The idea of employing automatic image processing in livestock welfare monitoring is not new (Van der Stuyft *et al.*, 1991; Tillett, 1991). Several studies have been carried out on comparing manual labelling of visits and water meter measurements (Madsen and Kristensen, 2005b; Meiszberg *et al.*, 2009). However, automatic monitoring of visits to estimate water use in a pig barn has never been reported in literature. Using a data-based dynamic (transfer function) model (Aerts *et al.*, 2008), the introduced approach estimates half-hourly water use from monitored drink nipple visits of pigs in one pen by using image analysis.

This technique helps to improve pigs' welfare since problems in having access to water or abnormal drinking behaviours in pigs can be reported before it harms their health. Moreover, since automatic image processing facilitates combining drinking behaviour analysis with analysing other behaviours like feed intake, it is more advantageous in comparison with conventional water meters.

2. MATERIALS AND METHODS

2.1. Animals and housing

This study comprised three weeks of data gathered during an experiment carried out in Agrivet research farm, Merelbeke, Belgium. Forty grower pigs (25.1±4.4 kg) were equally distributed over four fully slatted pens and balanced for sex, live weight and litter. The key specifications of the experiment were as follows: (1) Pens had a dimension of 2.25 meters by 3.60 meters. (2) Average indoor

[1] Water use is the total amount of water flowed in the drinker pipes. Some of this water is consumed by pigs and the rest is wasted. In this work the wasted water is not measured, so "water use" is considered.

C. (3) The experiment was carried out in winter[2], so the barn was heated by climate control with a set point temperature of C. (4) Light was switched on at 7 a.m. and continued until 7 p.m. (5) The feeding regime (daily amount of food per pen) was based on ad libitum access to food (commercial grower diet). (6) Each pen was equipped with a Honsberg Magnetic-Inductive MID008 water meter. These water meters had an accuracy of 2.5 % of measured value at the range of 2 to 10 litre/min and an accuracy of 0.5 % of full scale at the range of 0.05 to 0.2 litre/min. There was a nipple in the end of each pipe that had to reduce the flow to prevent the pigs spoiling water. Water meters were recording the measured water flow measurement each 5 minutes. Finally, it should be noted that this study was approved by the Ethical Committee of the Faculty of Veterinary Medicine at Ghent University, Belgium[3].

2.2. Data collection

During the experiment, video recordings of the pigs in the four pens were made. The research barn was equipped with black and white WV-BP330 CCD cameras installed in the rafters at the height of 2.3 meters to capture top-view images. For 12 years now M3-BIORES at KU Leuven is developing algorithms for top-view images because this solution is simple to implement in field conditions (Cangar *et al.*, 2008; Vranken *et al.*, 2005). Top view camera fitting is least disturbing for animals and produces the most useful data for the purpose of this study (Liang *et al.*, 2010).

Using Noldus MPEG Recorder software, images were recorded during 13 days (upon the schedule demonstrated in table 1) in 3 weeks for 12 hours per day, between 7 am and 7 pm, resulting in 156 hours of video. Videos were recorded in MPEG-1 format, with a frame rate of 25 frames per second, frame width of 720 pixels, frame height of 576 pixels and data rate of 64 kbps.

<u>**Place of Table 1**</u>

2.3. Image segmentation

The first step to process was to segment the image in order to find the location of the pigs. To segment the image, first, it was binarised to eliminate the background (Yang, 1994). Afterwards the pig's body was extracted as an ellipse (McFarlane and Schofield, 1995; Igathinathane *et al.*, 2008). Figure 1 (a, b) shows pigs locations identified in ellipses.

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[2] Average of outside temperature was 6.5 C with a maximum of 15.5 C and a minimum of -3.5 C.

[3] The experiments carried out in this work were also in accordance with EU Directive 2010/63/EU for animal experiments.

In order to find if a pig put his head at the drink nipple or not, it was necessary to identify the head (or ears) of the pigs. This was achieved by analysing the pigs body contour (Chaki and Parekh, 2012). Figure 2.a shows the pig's body with important points marked on it. Centroid of the pig's body image was taken as the reference in analysing his body contour profile. It was calculated using the equations 1 and 2. In equation 1, m_{pq} is the (p^{th} ,q^{th}) order torque of image function f(j,j) of the image I. In equation 2, X and Y of the centroid are calculated using the torque calculated in equation 1.

$$m_{pq} = \sum_{(i,j)\in I} i^p \times j^q \times f(i,j) \qquad (1)$$

$$X_{centroid} = \frac{m_{10}}{m_{00}}, Y_{centroid} = \frac{m_{01}}{m_{00}} \qquad (2)$$

By calculating the distance of the pig's body contour pixels from the centroid of his body, a distance profile shown in figure 2.b was achieved. Points 3 and 5 relate to the ears of the animals. So, by finding minima and maxima of this plot, it was possible to detect ears and consequently the head of the animal.

Place of Figure 1

Place of Figure 2

2.3.1. Detection of drink nipple visits

Visually, the posture and position of pigs while being at the drink nipple is characteristic and easy to recognise. The criteria established for the drink nipple visit algorithm was that the pig had to stand still in the area adjacent the drink nipple and keep its snout in the water outlet for at least 2 seconds. Consequently, duration of the visit was registered. By definition, a visit is reported if a points 3 or 4 (shown in figure 2) inside an ellipse is detected closer than 10 pixels to the drink nipple. Since the water outlet used in our experiments was directional, pigs could only drink if they stood in a certain position in the region shown in figure 3 and, as a result, only one pig at a time could drink (Magowan *et al.*, 2007).

2.4. Water use estimation using dynamic data-based modelling

Final goal of this work was to estimate half-hourly water use in a pig barn by analysing half-hourly duration of drink nipple visits. To achieve that purpose, a data-based dynamic (or Transfer Function: TF) model was developed to quantify the dynamics of water meter measurements and to relate it with half-hourly duration of visits. Therefore, the main objective of the model was to estimate water use in a pen by only analysing pen image automatically.

Place of Figure 3

First, a single-input, single-output (SISO) system was used to model the water use as function of half-hourly duration of visits. The model structure used could be described as follows

$$w(t) = \frac{B_d(z^{-1})}{A(z^{-1})} d(t - n.t_T) \qquad (3)$$

where $w(t)$ is the half-hourly water measurement; t represents discrete-time instants with a measurement interval of thirty minutes; $d(t)$ represents the "half-hourly duration of visit" as the input of the model. $n.t_i$ is the number of the time delays between each input i and their first effects on the output; $A(z^{-1})$ is the denominator polynomial and equals $1 + a_1 z^{-1} + a_2 z^{-2} + \cdots + a_{n_a} z^{-n_a}$; $B_i(z^{-1})$ is the numerator polynomials linked with the inputs i and are equal to $b_{0i} + b_{1i} z^{-1} + b_{2i} z^{-2} + \cdots + b_{n_{bi}} z^{-n_{bi}}$; a_j , b_i are the model parameters to be estimated; z^{-1} is the backward shift operator, defined as $z^{-1}.y(k) = y(k-1)$; n_a, n_{bi} are the orders of the respective polynomials.

The model parameters were estimated using a refined instrumental variable approach with the Captain toolbox in Matlab (Young, 2011). In order to build the model, different combinations for n_a, n_{bd} and nt_d were calculated. More specifically for the SISO model which has only one input, n_a ranged from 1 to 2, n_{bd} from1 up to 2 and n_{td} from 0 to 2. Therefore, to identify the first SISO model in total 12 (2x2x3) possible TF models were calculated. The resulting models were evaluated by the coefficient of determination R_T^2 (Young and Lees, 1993) and an identification procedure was used to select the most appropriate model order based on the minimisation of the Young Identification Criterion (YIC) explained in (Young and Lees, 1993). The smaller the variance of the model residuals in relation to the variance of the measured output, the more negative this term becomes.

3. RESULTS

The aim of this study was to quantify the dynamics of the water use in a pig barn and to relate it to the time pigs spent on drinking. Figures 4a, 4b and 4c compare half-hourly duration of drink nipple visits of pigs with water meter measurements of pen 3 for 3 days of the experiment and table 2 presents the results of evaluating the model for the whole experiment (13 days). As observed in these graphs, water use followed the trend of the half-hourly duration of visits.

Place of Table 2

When applying the modelling approach to the data of the whole experiment (13 days and 24 hours a day) the YIC criterion selected models that were predominantly first order (equation 4), stable (namely all of the poles within the unit circle) and with highest R_T^2. The optimal model structure was described by $n_a=1$, $n_{bi}=1$ and $nt_d=0$ as demonstrated in equation 3.

$$w(t) = \frac{b_d z^{-1}}{1+a_1 z^{-1}} d(t) \quad (4)$$

<u>Place of Figure 4</u>

Result of using the applied transfer function model to estimate water use is shown in figure 5.

The specific values for the model parameters (a_1 and b_d) are presented in table 3. The model described the half-hourly measured water use over the 13 days with R_T^2 of 92%. As seen in the table, YIC is optimally low and the standard deviation of the a-parameter and b-parameter is trivial.

<u>Place of Table 3</u>

<u>Place of Figure 5</u>

4. DISCUSSION

Automatic detection of animal behaviour has proved useful to farm managers. One application is monitoring of drinking which is a key behaviour in pigs and relates to many other welfare indexes. In normal situations pigs show a stable diurnal drinking pattern (Madsen *et al.*, 2005a), whereas outbreak of diseases, changes in the quality of feed or ventilation problems often make the pigs' drinking behaviour deviate from the normal pattern. The existence of a drinking pattern and the specificity of drinking behaviour are criteria that allow using drinking behaviour as a predictor for health or production problems (Meiszberg *et al.*, 2009). The findings of the study reported in Musial *et al.*, 1999 indicate that water intake for the pig follows a drinking pattern. This pattern is affected by different factors such as drinker design (Brumm *et al.*, 2000), diet (Shaw *et al.*, 2006), weight and size of pigs (Frederick *et al.*, 2006), etc. Thus, analysing this pattern can yield useful information on suitability of pigs welfare.

Adopting automatic video processing is a popular technology in pigs welfare monitoring (DeShazer *et al.*, 1988; Tillett *et al.*, 1997; Lind *et al.*, 2005). In this work, an innovative approach was chosen to estimate fattening pigs' water use by automatic vision technology. Using image processing techniques, duration a pig stays at the drink nipple was calculated. To improve the accuracy of the applied algorithms, using image contour analysis methods, important parts of pigs' body, namely ears, head and head, were detected. This helped to find if a pigs stood in a standard drinking position. Comparing applying of this method with labelling of the drink nipple visits proved the method to be accurate.

Real time monitoring of growing pigs' water consumption seems to be a possible way of improving management (Bird and Crabtree, 2000). In order to be able to detect changes in drinking behaviour, it is crucial to have a well-founded model to predict the expected behaviour. In this work, a model was developed to relate duration of visits to the water use. Developing a transfer function model in MATLAB Captain Toolbox resulted in several stable models with various delay, a-parameter and b-parameters. The simplest model was a first-order model without a delay. Adapting this model to those two parameters, one as input (duration of visits) and the other as output (water use) resulted in R^2 of 92%. Therefore, it can be concluded that by monitoring drink nipple visits in a pen, one can accurately estimate amount of water pigs use. The significance of this work lies in its ability to automatize drinking behaviour of pigs which is but one of many behaviours that can be monitored automatically using video processing techniques.

4. CONCLUSION

In this work, an innovative approach was chosen to investigate the opportunities of estimating water use of fattening pigs automatically by vision technology. Estimating water use of pigs can help us to understand how drinking behaviour of pigs is related to their water use. As such, this method offers many potential applications to improve animal husbandry management.

The analysis described above indicates that it is possible to perform real-time camera vision-based water use estimation in a pig pen. This analysis may contribute to improve automatic analysis of drinking behaviour based on top-view video processing. The results showed that by automatic image processing and transfer function modelling, half-hourly water use could be estimated with high accuracy. The presented approach is able to estimate the half-hourly water use of pigs in a barn with an accuracy of 92%.

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Figure Headings

FIGURE 1: a. Pigs in a pen of 2.25 m by 3.60 m; b. Pigs location identified in ellipses

FIGURE 2: a. Important points of a pig's body contour; C is the centroid and d_i is the distance of the centroid to the point I, i=1, 2, …, 6; b. Distance of pixels on body's contour from the centroid of body

FIGURE 3: Possible drinking region for pigs at the drink nipple

FIGURE 4: Half-hourly duration of visits in pen 3 to the drink nipple vs. water meter measurements a. Experiment day 1 (R^2= 0.94); b. Experiment day 8 (R^2= 0.90) ; c. Experiment day 15 (R^2= 0.89)

FIGURE 5. The resulting model (– –) of the data-based SISO model versus measured (—●—) water use in 24 hours (first day of the experiment)

Table

Table 1. Recording days of the experiment; on some of the days, recording had been stopped due to physiological measurements. Discussing these measurements is out of the scope of this paper.

Week 1				Week 2					Week 3			
Day 1	Day 3	Day 4	Day 6	Day 8	Day 10	Day 11	Day 13	Day 14	Day 15	Day 17	Day 18	Day 20

Table 2. R^2 between the hourly duration of visits to the drink nipple vs. water meter measurements in 13 days of the experiment; total average R^2 is 0.92; on some of the days, recording had been stopped due to physiological measurements. Discussing these measurements is out of the scope of this paper.

Day	Pen 1	Pen 2	Pen 3	Pen 4
1	0.93	0.92	0.94	0.87
3	0.92	0.90	0.94	0.90
4	0.97	0.92	0.95	0.94
6	0.89	0.92	0.95	0.92
8	0.90	0.97	0.90	0.94
10	0.93	0.91	0.90	0.94
11	0.92	0.94	0.94	0.96
13	0.92	0.93	0.90	0.88
14	0.91	0.90	0.96	0.90
15	0.88	0.90	0.89	0.90
17	0.95	0.91	0.89	0.88
18	0.96	0.96	0.97	0.95
20	0.90	0.87	0.90	0.91
Total	0.92	0.92	0.93	0.91

Table 3. Specification of the dynamic linear model developed using water use measurement as the output and half-hourly duration of visits to the drink nipple as input

YIC	R^2	Parameter estimate
-5.811	0.92	a_1 = -0.0768 (0.0153)* = 0.0374 (0.0005.9)

* The parameter estimates are accompanied by associated standard deviations in parenthesis. The basis for computation of the standard deviation is each half-hourly computation.

Figure 1

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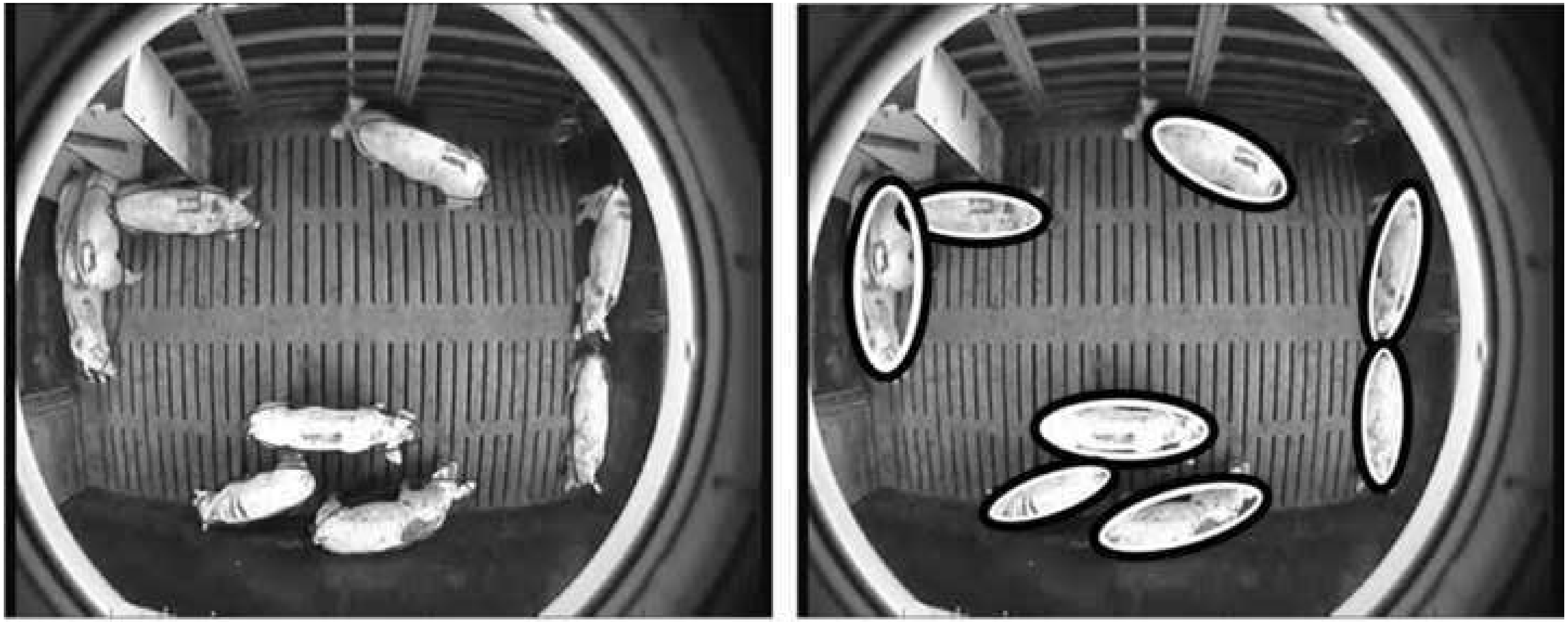

(a) (b)

Figure 2

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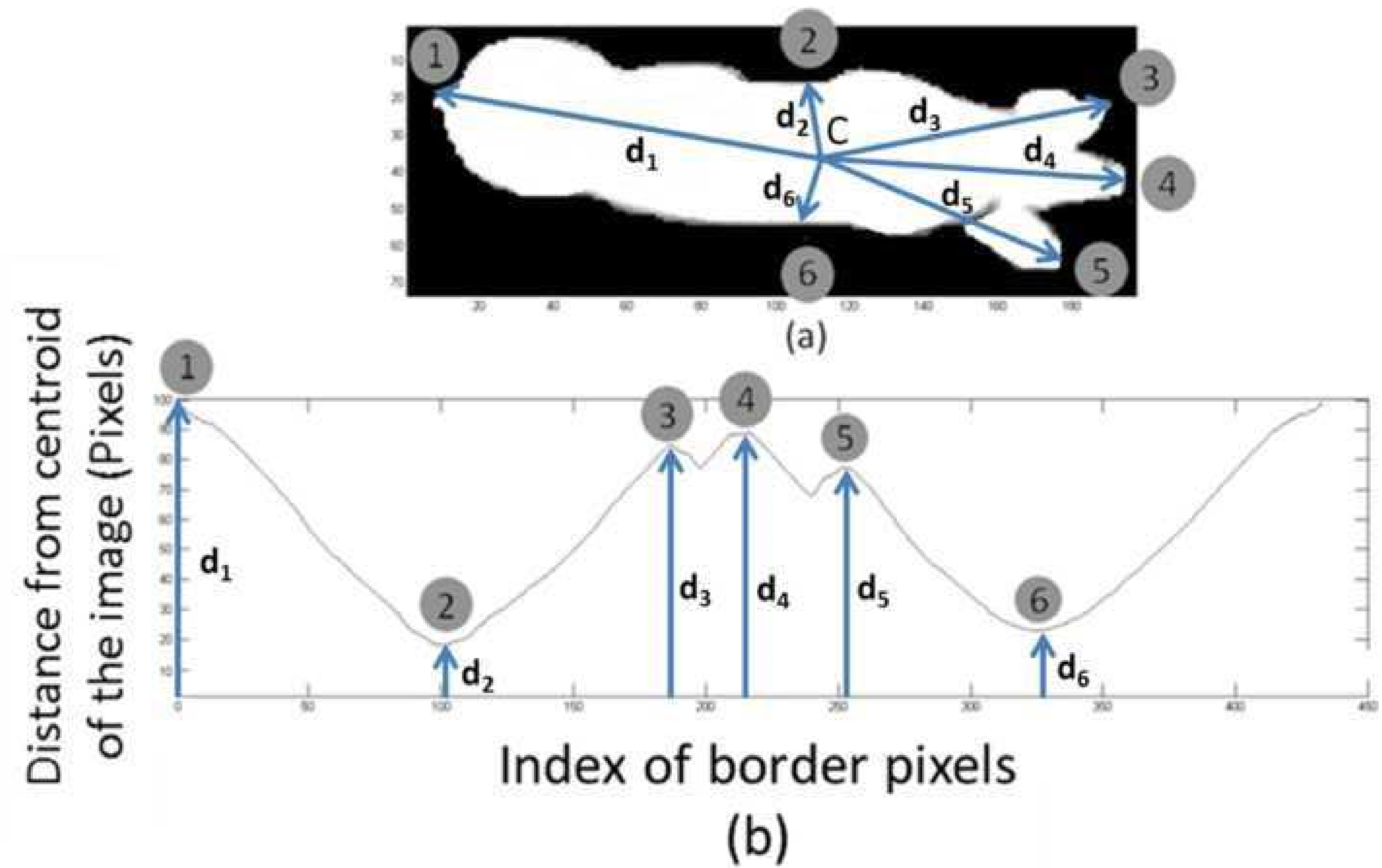

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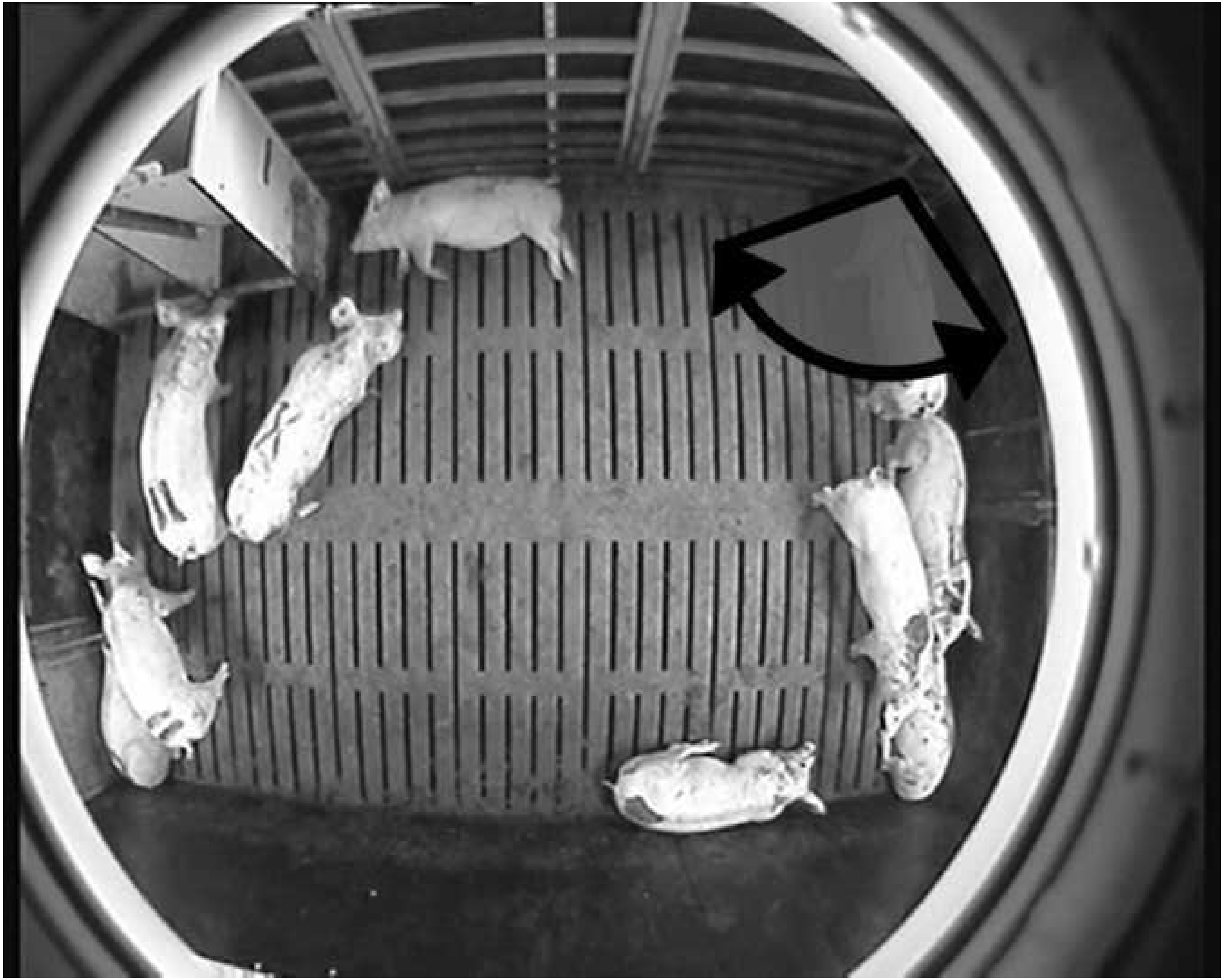

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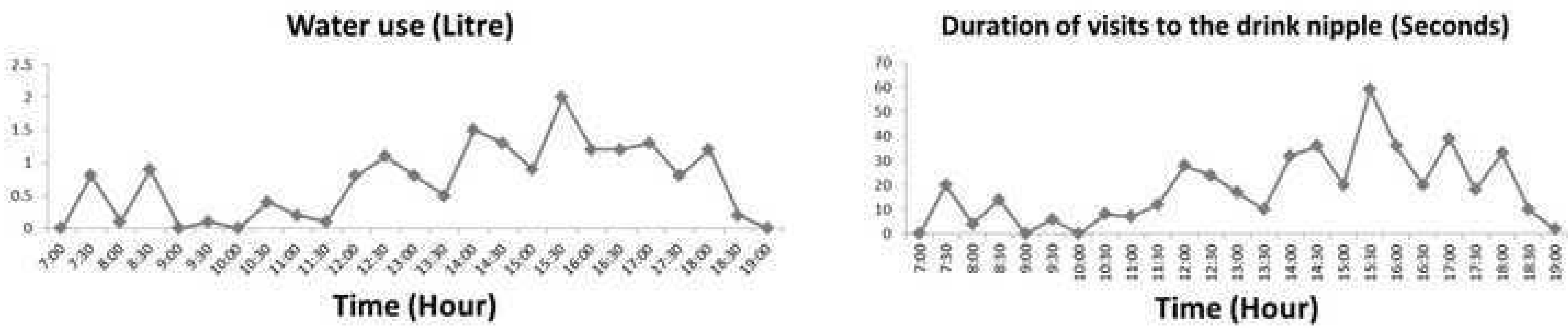

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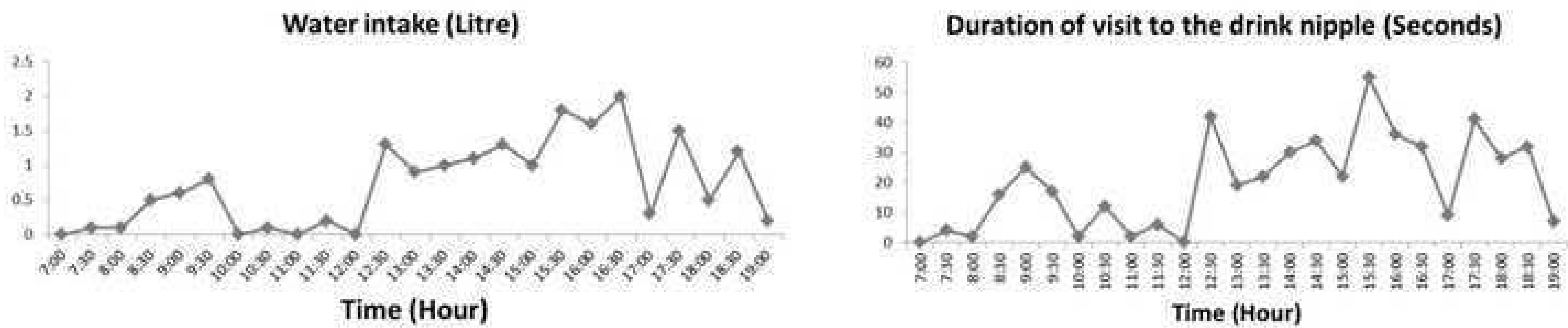

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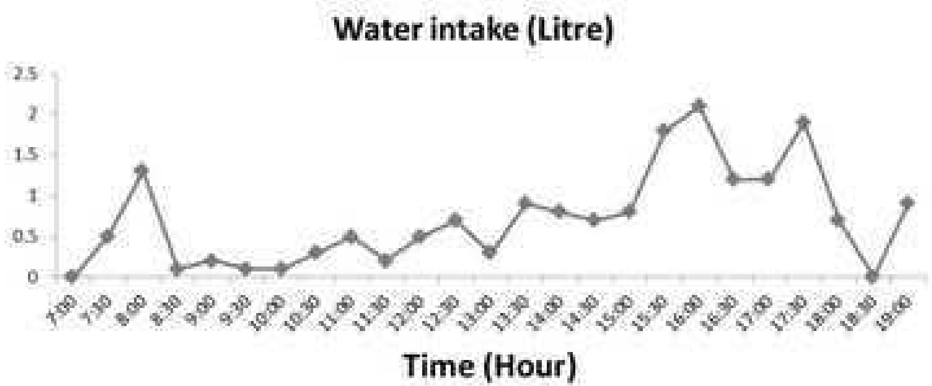

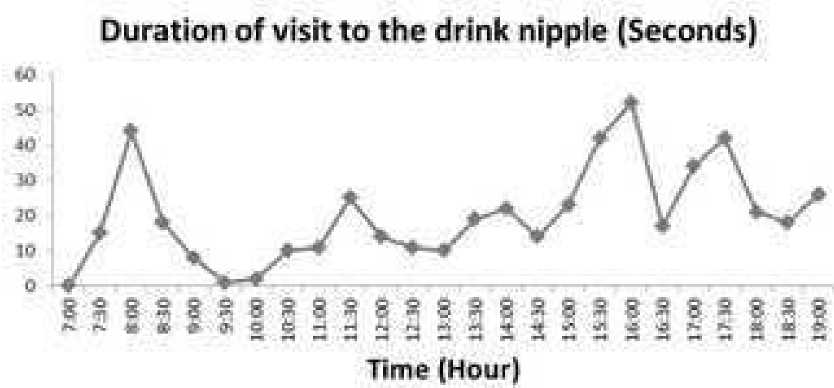

Figure 5
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