Nasirahmadi A, Richter U, Hensel O, Edwards S, Sturm B.

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*Computers and Electronics in Agriculture* 2015, 119, 184-190.



**DOI link to article:**

http://dx.doi.org/10.1016/j.compag.2015.10.023

**Date deposited:**

04/11/2015

**Embargo release date:**

12 November 2016

# Using machine vision for investigation of changes in pig group lying patterns

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## Abstract

Pig lying patterns can provide information on environmental factors affecting production efficiency, health and welfare. The aim of this study was to investigate the feasibility of using image processing and the Delaunay triangulation method to detect change in group lying behavior of pigs under commercial farm conditions and relate this to changing environmental temperature. Two pens of 22 growing pigs were monitored during 15 days using top view CCD cameras. Animals were extracted from their background using image processing algorithms, and the x–y coordinates of each binary image were used for ellipse fitting algorithms to localize each pig. By means of the region properties and perimeter of each Delaunay Triangulation, it was possible with high accuracy to automatically find the changes in lying posture and location within the pen of grouped pigs caused by temperature changes.

**Keywords:** pig, lying behavior, image analysis, Delaunay Triangle.

## 1. Introduction

The welfare of an animal can be defined using its behaviour, physiology, clinical state and performance (Averos et al., 2010; Costa et al., 2014). One of the most important factors

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affecting welfare throughout the stages of breeding, growth and maturity is the environment in which animals are maintained. The environmental temperature has direct effects on pig behaviour. At high environmental temperatures, pigs tend to lie down in a fully recumbent position with their limbs extended and avoid physical contact with others, to be able to transfer as much heat as possible to the environment, and they prefer to lie in wet parts of the pen. At low environmental temperatures, pigs will adopt a sternal lying posture and huddle together (Hillmann et al., 2004; Huynh et al., 2005; Spoolder et al., 2012; Costa et al., 2014; Debreceni et al., 2014).

Observations of the lying behaviour of pigs have already been made in numerous studies, often in conjunction with other behavioural and/or physiological features of the animals. However, these investigations have generally been carried out under experimental conditions, reflected by a small number of pigs in the pen. The influence of floor and surface temperature on thermal behavior of pigs was investigated by Geers et al. (1990). Experiments have been carried out to study the lying postures and space occupation (Ekkel et al., 2003; Spoolder et al., 2012), and to assess optimal temperature ranges for fattening pigs of different weights kept in pens (Hillmann et al., 2004). The results showed that with increasing temperature, pigs were more often lying in the dunging area and without contact with pen mates, whilst pigs showed huddling at lower temperatures. The same result was reported by Huynh et al. (2005) when investigating the effect of high temperature and humidity on the behaviour of growing pigs. Such data have generally been collected either by direct observation of the pen or with the aid of video recordings. These methods are both labour-intensive and time-consuming (Stukenborg et al., 2011).

Image processing has been an important technique for a wide variety of applications in agriculture and food engineering. This technique is an alternative, cheap and non-contact way to replace human observation of the animals and causes no disruption to the animals' normal behaviour (Tillet et al., 1997; Shao and Xin, 2008; Costa et al., 2013; Kashiha et al., 2014). There are several recent studies in the literature where computer vision has been applied to pig group behaviour (Ahrendt et al., 2011; Kashiha et al., 2013; Viazzi et al., 2014; Ott et al., 2014). Image processing features were used as inputs for environmental control in piglet houses by Wouters et al. (1990). A real-time image processing system was developed to detect movement and classify thermal comfort state of group-housed pigs based on their resting behavioural patterns by Shao and Xin (2008). The results showed that this system effectively detects animal movement, and correctly classifies animal thermal behaviour into cold, comfortable, or warm/hot conditions. Recently, another research group has performed image processing in pigs focusing on behaviour classification (Costa et al., 2013). The aim of this study was to develop an innovative method for measuring the activity level of pigs in a barn in real time. An infrared-sensitive camera was placed over two pens of the piggery, images were recorded for 24 h a day for eight days during the fattening period, and the activity and occupation indices were calculated every second in real time. In a similar study, Costa et al. (2014) evaluated the relationship between pig activity and environmental parameters in a pig building by means of image analysis. They showed that there was a significant relation between pig activity index and ventilation rate, temperature and humidity.

Although these studies have concentrated on lying parameters by image analysis, no specific patterns for changes in lying behaviour in different environmental temperatures were investigated in groups of pigs under commercial farm conditions. Therefore, the main purpose of this study was to identify the lying pattern of pigs, the location of pigs during lying time and the distance between them using image analysis technology based on a Delaunay Triangulation (DT) method involving charge-coupled device (CCD) cameras.

## 2. Material and methods

### 2.1. Animals and housing

The observations were conducted at a commercial pig farm in the UK. A series of rooms each housed 240 finishing pigs; rooms were 14.35 m wide × 20.00 m long, mechanically ventilated and subdivided into 12 pens, each 6.75 m wide × 3.10 m long, and with a fully slatted floor. All pens were equipped with a liquid feeding trough and one drinking nipple. From the 12 pens in a room, two pens were selected for the experiments, each containing 22 pigs (Fig. 1). The white fluorescent tube lights were switched on during day and night. Room temperature was recorded every 15 minutes over the total experimental period with 16 temperature sensors (TE sensor Solutions, 5K3A1 series 1 Thermistor, Measurement Specialties Inc. USA) arranged in a grid pattern. The experimental phase started after placement of about 30 kg pigs in the pen and lasted 15 days.

## 2.2. Image processing

The camera (Sony RF2938, EXview HAD CCD, Board lens 3.6 mm, 90$^{o}$) was located 4.5 meters above the ground with its lens pointing downward and directly above each pen to get a top view (Fig. 1). Cameras were connected via cables to a PC and video images from the cameras were recorded simultaneously for 24 hours during the day and night and stored in the hard disk of the PC using Geovision software (Geovision Inc.) with a frame rate of 30 fps. The original resolution of an extracted image from the video was 640 × 480 pixels and images were extracted from the 360 h of recorded videos. To develop algorithms for continuous automated identification of changes in the lying pattern of the pigs, the location of each group of pigs needs to be known during defined periods. After downloading the recorded data, the video files were visually investigated and labelled (24 h/day for five days selected from the first 15 days) in order to evaluate animal lying times during the study. Four 30-min durations (duration 1, from 6.00 to 6:30AM; duration 2, from 12.00 to12:30 PM; duration 3, from 18.00 to 18:30 PM; duration 4, from 0.00 to 0:30 AM) were selected based on observations that showed almost all pigs to be lying in these times during the 24 hours in a day.

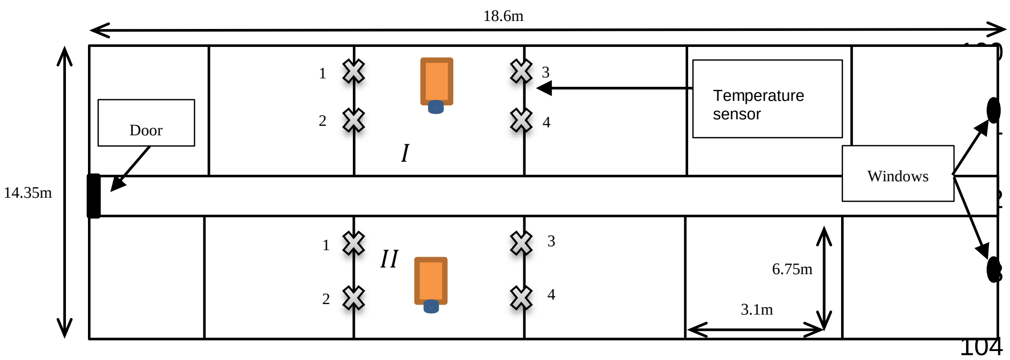


**Fig. 1. Top view of the research barn.**

In order to remove Barrel distortion in the images, camera calibration was carried out using the ‘Camera Calibration Toolbox’ of Matlab® (the Mathworks Inc., Natick, MA, USA) and 25 images of a checkerboard pattern were taken in different orientations for each camera (Wang et al., 2007). Each pen was virtually subdivided into four zones (Fig. 2A); zone four being near the corridor and zone one against the outer wall. Images from each camera were then analysed using background subtraction algorithms. The threshold of grey image was determined based on Otsu's method, which chooses the threshold to minimize the intra-class variance of the black and white pixels (Otsu, 1979). Then the threshold was applied to convert the greyscale image into a binary [0, 1] image, and 1 assigned to the object and 0 assigned to the background. Erosion and dilation orders with disk structure were used for smoothing of edges. To remove small objects from the image, a morphological closing operator with a disk-shaped structuring element was used (Gonzalez and Woods, 2007) (Fig. 2B).

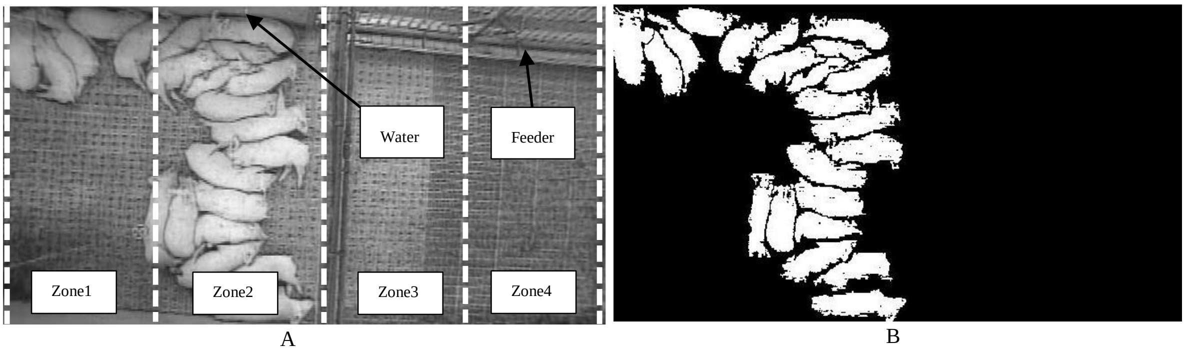


**Fig. 2. The pen and four zones in it (A), binary image after applying morphological operators (B).**

Since each single pig in the image is similar to an ellipsoidal shape, the x–y coordinates of each binary image could be used for ellipse fitting algorithms to localize each pig. As a result, ellipse parameters such as “Major axis length”, “Minor axis length”, “Orientation” and “Centroid” could be calculated for all fitted ellipses to separate the touching pigs (Fig. 3). Therefore each pig’s body was extracted as an ellipse using the direct least squares ellipse fitting method and the aforementioned ellipse parameters (McFarlane and Schofield, 1995; O’Leary, 2004; Kashiha et al., 2013).

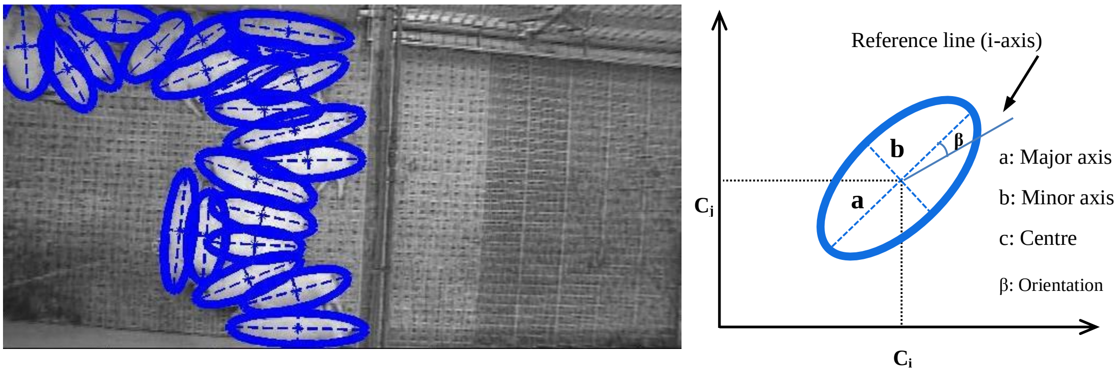


**Fig. 3. Ellipse fitted to each pig with their parameters.**

The Delaunay Triangulation (DT) of a set of P points on a plane is defined to be a triangulation such that the circumcircle of every triangle in the triangulation contains no point from the set in its interior and the circumcircle of a triangle was the unique circle that passed through all three of its vertices (Hansen et al., 2001). The DT maximized the minimum angle of all the angles of the triangles in the triangulation and tended to avoid skinny triangles. A triangle is called Delaunay regarding to a point P if P does not lie inside the circumcircle of triangle (Fig. 4).

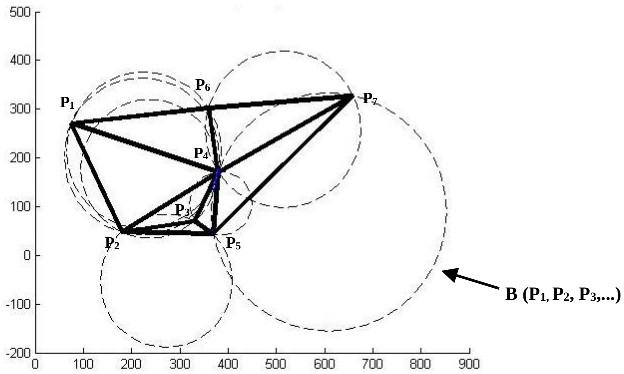


**Fig. 4. The DT for the point set $P_1$, $P_2$….$P_7$ in a plane. B is the circumscribing circle of Delaunay triangle.**

In this study the method used for the computation of the DT was implemented in MATLAB software and we used the centre of each ellipse (Fig. 3) obtained from the image as a triangulation point. Furthermore, for obtaining a set of non-overlapping triangles with the minimum of the inner angles, at first the algorithm in MATLAB transformed the 2D points to 3D, here it computes the convex hull in 3D, and then projected the lower part of the hull back to 2D to obtain the triangulation (Häfner et al., 2012). Fig. 5 shows the black colour channel with 22 vertexes (number of pigs) of a sample image from the image database along with the DT.

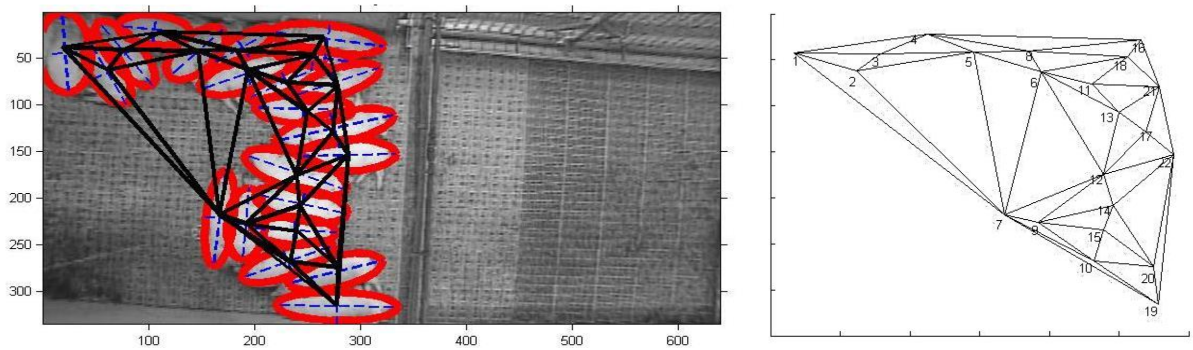


**Fig. 5. The DT along with the fitted ellipse.**

The perimeter of each triangle in the DT shape reflects how closely pigs touch each other, and is calculated as: $P = l1 + l2 + l3$ where $l$ represent the length of side of the triangle (in pixels).

## 3. Results and discussion

In order to validate the automated image processing technique, the percentage of frames with correct estimation of the number of pigs in the pen with reference to manual labelling was determined. There were 15 (days) ×30 (min) × 4 (times in a day) × 2 (pens) of video duration, and each video consisted of 1800 frames (one frame per second). From the 108000 (15×30×60×4) extracted frames for each pen, 19592 were processed in pen *I* and 20306 frames in pen *II* as described in the following paragraph.

The four time periods were selected in times when almost all pigs were lying. In the case that pig(s) were not lying during the aforementioned period, we used the image locomotion method which was defined by Kashiha et al. (2014) in order to automatically select the lying pigs in each frame; after using the ellipse fitting technique, angular and linear movements of each ellipse between two consecutive frames were calculated. By visual investigation of the pigs' movement time in the video files, we selected the first frame $F_t$ (at time zero) and the next one $F_{t+5}$ (after five seconds) (Fig. 6). According to the figure, due to pig movement the angular and linear movement of the mentioned ellipse from frame $F_t$ to $F_{t+5}$ was changed; the pig initially had angular movement then moved from $C(i_1,j_1)$ to $C(i_2,j_2)$ in the next frame. Finally, after finding the pigs in motion, by removing these active pixels in the ellipse fitting algorithm we fitted ellipses to lying pigs only in the last frame ($F_l$).

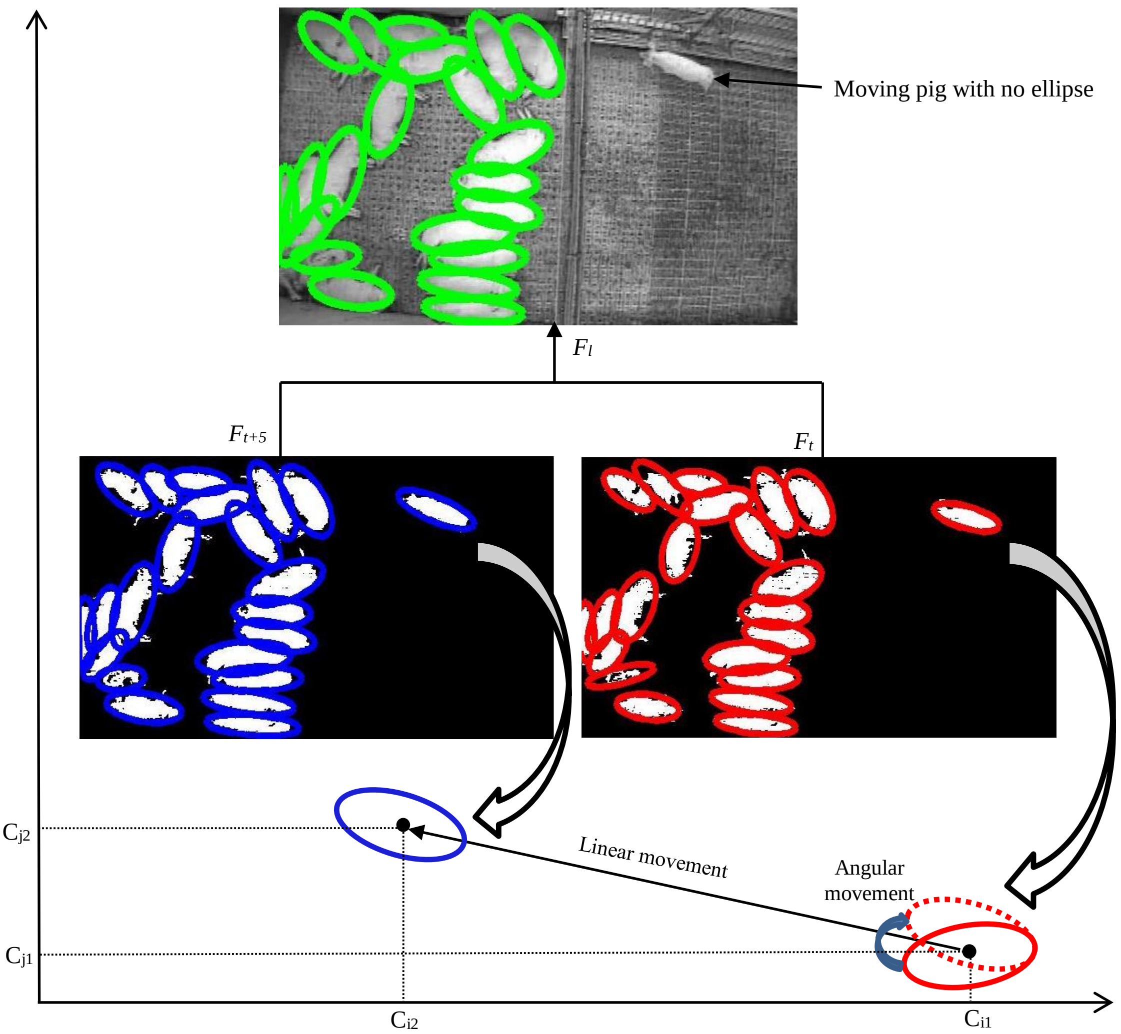


**Fig. 6. Pigs with fitted ellipse in two frames $F_t$ and $F_{t+5}$, the movement pig was not selected in frame $F_l$ and the ellipse was fitted for lying pigs in final grey image.**

The estimated number of pigs in each processed image was calculated and then compared with the number of pigs in that pen. The results showed that the percentage of frames with correct estimation of pigs in the pen using image processing techniques was 95.8(±2) %, on average (Table 1). There were a few reasons behind false identification: first and foremost because the project was carried out in a commercial farm, there was a water pipe in the middle of each pen (2.5 meter from the floor) which caused some invisible areas in images. Furthermore, as time progressed, soiling by flies dirtied the camera lenses and reduced the visibility.

**Table 1. The percentage of frames with correct estimation of pigs in the pen from automated image processing compared to manual labelling.**

| | Pen | | | |
|---|---|---|---|---|
| | *I* | | *II* | |
| Day | Number of frames analysed | Correct estimation (%) | Number of frames analysed | Correct estimation (%) |
| 1 | 1290 | 96.5 | 1359 | 95.0 |
| 2 | 1199 | 94.4 | 1378 | 97.6 |
| 3 | 1338 | 95.2 | 1400 | 94.9 |
| 4 | 1287 | 97.1 | 1321 | 98.3 |
| 5 | 1354 | 95.0 | 1298 | 92.6 |
| 6 | 1360 | 98.6 | 1387 | 97.7 |
| 7 | 1257 | 97.1 | 1385 | 93.2 |
| 8 | 1290 | 94.4 | 1355 | 94.0 |
| 9 | 1327 | 91.4 | 1375 | 93.9 |
| 10 | 1200 | 96.8 | 1342 | 95.3 |
| 11 | 1321 | 99.5 | 1370 | 97.3 |
| 12 | 1385 | 95.0 | 1346 | 97.0 |
| 13 | 1308 | 93.3 | 1321 | 98.5 |
| 14 | 1366 | 93.3 | 1295 | 94.2 |
| 15 | 1310 | 98.9 | 1374 | 96.3 |
| **Total** | **19592** | | **20306** | |

The averages temperatures of four sensors within each pen (see Fig. 1) in the two pens during the 15 days of study are shown in Fig. 7. Over the recording period, temperatures ranges were 14.3-22.3 $^{o}$C for pen *I*, and 13.7-22.2 $^{o}$C for pen *II*. The temperature patterns showed more fluctuation in the first week of study and had a constant pattern in the second week, possibly because of better heat balance between the pigs' body heat emission and environmental temperature.

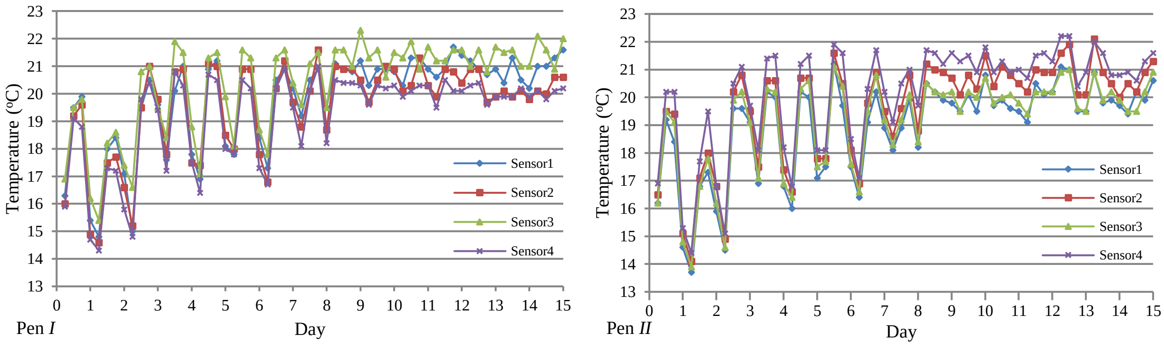


**Fig. 7. Temperature for both pens for 15 days.**

Fig. 8 shows sample images from the image database with the respective DT at different temperatures. From this figure it can be seen that the Mean Value of Perimeters (MVP) of each triangle was different as average temperature changed during the study. The MVP was higher at 22.3ºC than at other temperatures, indicating that pigs had more separation during lying time at that temperature, while at lower temperature the MVP declined and pigs were lying closer or huddled together. Therefore this feature can be used for distinguishing different lying patterns in the DT and indicates that the output could be used for assessing the uniformity of room temperature for improving pig welfare.

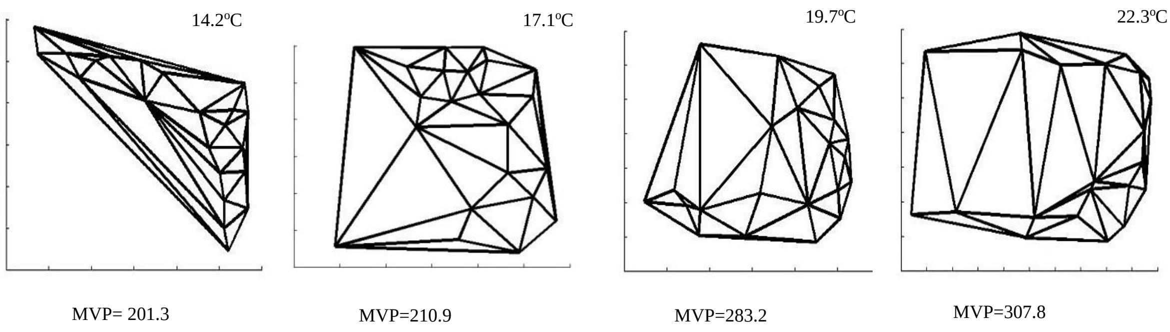


**Fig. 8. The DT patterns in different environmental temperatures.**

The extracted data from the images were submitted to regression analysis (SPSS® 21, IBM, USA) to evaluate the effects of environmental temperature on the MVP in both pens (Table

2). The relationship between temperatures and the MVP pattern was statistically significant (<0.001) for both pens.

**Table 2. Linear regression analysis for effect of environmental temperature on the MVP in both pens.**

| Pen | Equation (± Std. Error) | $R^2$ | *p-value* |
|---|---|---|---|
| Pen *I* | MVP= -340.3 (±29.0) + 31.3 (±2.0) temperature | 0.81 | <0.001 |
| Pen *II* | MVP= -342.4 (±27.4) + 31.2 (±1.9) temperature | 0.82 | <0.001 |

In the presented study, video monitoring of pig lying behaviour, which was performed through image processing techniques and using the DT, showed that at higher temperatures, pigs lay down with their limbs extended and in a fully recumbent position so that the MVP was higher than at lower temperatures. In contrast, at lower environmental temperatures pigs adopted a body posture that minimized their contact with the floor and maximised the contact with other pigs, so that the MVP was lower. This result is in agreement with other researchers (Shao and Xin, 2008; Costa et al., 2014) who have reported that in higher temperatures pigs tended to spread out, and in a cold situation they tried to huddle or touch each other. Different MVPs in different temperatures for the two pens during this study are shown in Fig. 9 and 10.

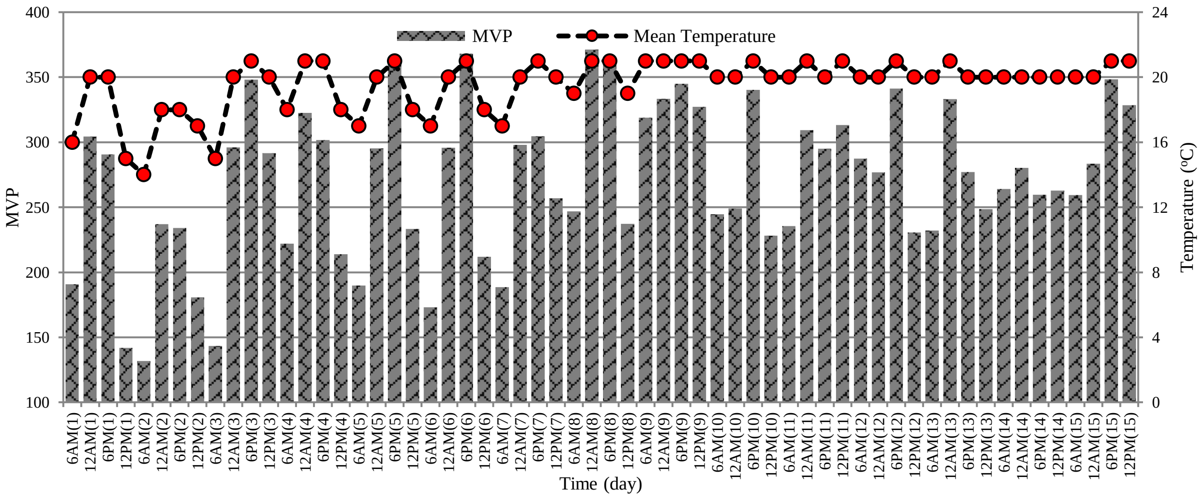


**Fig. 9. The MVP over 15 days assigned with their temperature (°C) in pen *I*.**

By comparing temperatures in the two pens and according to the MVP data, pigs tended to lie further apart and had less contact in pen *I* (Fig. 9) than in pen *II* (Fig. 10). In some cases the MVP was different at identical temperatures in both pens. This is likely due to additional environmental influences (i.e. different ventilation rates in different locations in each pen) which could not be controlled as the project was carried out in a commercial pig farm.

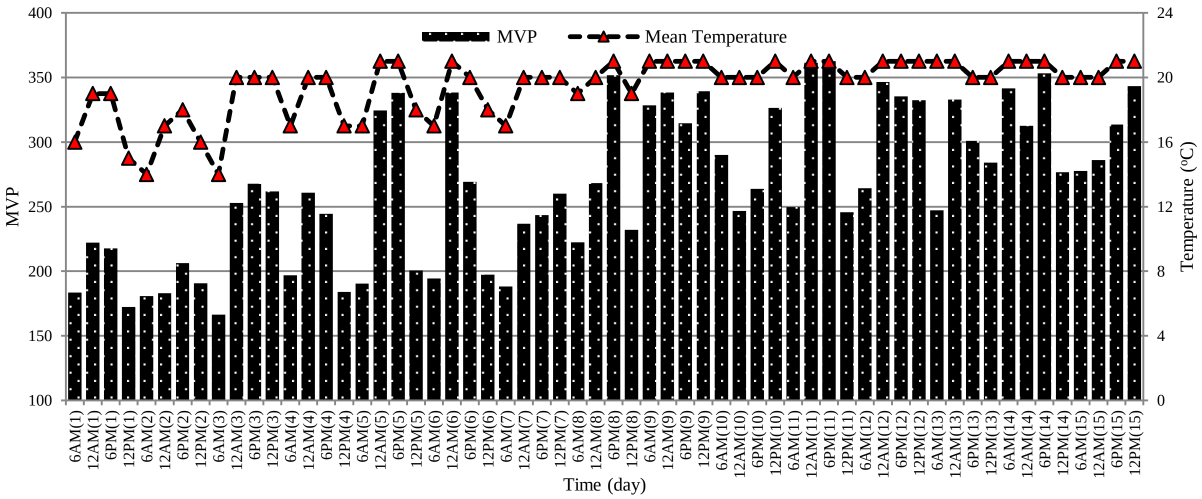


**Fig. 10. The MVP over 15 days assigned with their temperature (ºC) in pen *II*.**

Employing modern technology has helped farm managers to improve animal welfare (Kashiha et al., 2014). The proposed method can help to monitor a large number of pigs in different commercial pens and to adjust room temperature for higher welfare and economic outputs. Knowing the position of each pig in the pen during lying time can be used to assess and improve animal welfare, since lying in the dunging area has negative consequences for hygiene, resulting in dirtier pigs and pens (Spoolder et al., 2012). Using the x-y coordinates of each pig in binary images and the centroid of each fitted ellipse indicated the specific position of each pig in the pen during the lying time (see Fig. 11). Over the 15 days, the percentage of lying positions was higher in zone 4 (near the corridor) and zone 3 when the temperature was lower in both pens; similar results were reported by Costa et al. (2014). According to Fig. 11, in both pens pigs tended to lie in zone 4 and 3 more than other zones, but when temperature increased they tended to lie more often in zone 1 and 2. The percentage of time in different lying zones was different between the two pens during the study; in pen *II* more than 70% of the animals were in zone 4 for the first 6 days while there was a more even distribution between zones 3 and 4 in pen *I*.

The lying zone which pigs choose is determined by a number of factors including design of the pen, location of feeder and drinker, and environmental conditions relating to temperature, air velocity and humidity (Spoolder et al., 2012; Costa et al., 2014). In the two investigated pens, feeder and drinker locations were the same and the temperature sensors showed almost equal value for both pens during the study. However, with the ventilation system in use, the air velocity pattern or the volume of air displacement may have differed between the pens to cause the different distribution in lying positions.

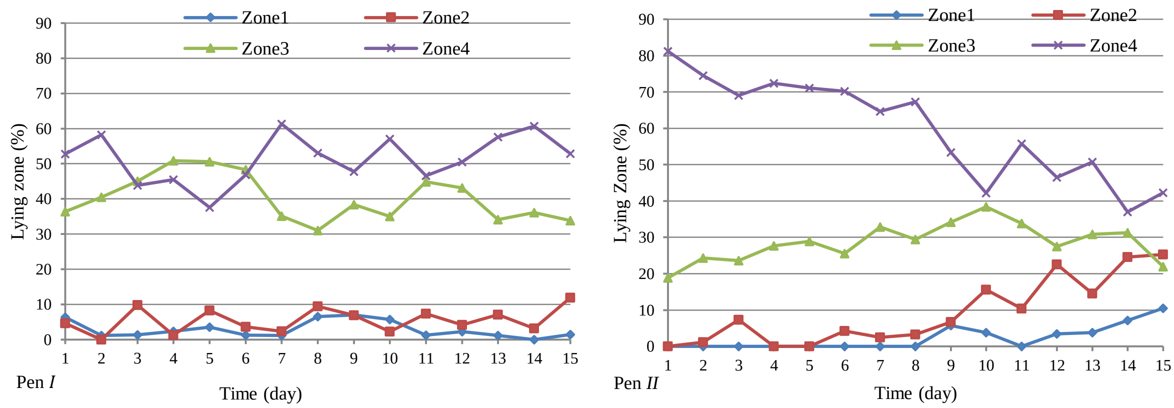


**Fig. 11. Mean value of location of lying pigs in different zones over 15 days.**

## 4. Conclusion

In conclusion, it was shown that the developed method can measure the exact location of each pig during lying time and changes in lying pattern with a high degree of accuracy in commercial farm conditions using the DT, and relate changes in lying pattern to temperature changes. Therefore this method could contribute in the future as an important and economically feasible technique in commercial farms for assessment of livestock welfare in terms of the adequacy of environmental conditions. This is an important step towards the development of an automated system that can detect exact lying patterns and location of pigs during lying time by image features over time.

However this method needs more study for defining different lying patterns and future development of a method for controlling and adjusting the environmental factors in a fully automated way in order to having the best pig lying patterns and location for improving animal welfare. Finding the best solutions for environmental challenges like flies which cover camera lenses with dirt and reduced visibility needs to be investigated before the fully automated machine vision technique can be implemented in commercial pig farms.

**Acknowledgments**

The authors wish to thanks the Innovate UK project 101829 “Green Pigs” for the financial support and Midland Pig Producers for access to commercial pig facilities.

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