REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

A Comprehensive Analysis of Pig Behavior Recognition in Conventional Pig Farming

Jitendra Kumar Katariya[1]*, R Kavitha[2], Anushka Sharma[3]

*[1]Assistant Professor, Department of Computer Science & Application, Vivekananda Global University, Jaipur, India, Email Id- jitendra.kumar.katariya@vgu.ac.in, Orcid Id- 0009-0000-9940-9022

[2]Professor, Department of Computer Sceince and Information Technology, Jain (Deemed to be University), Bangalore, India, Email Id- kavitha.r@jainuniversity.ac.in, Orcid Id- 0000-0001-6722-9297

[3]Assistant Professor, Department of Computer Science & Engineering, Sanskriti University, Mathura, Uttar Pradesh, India, Email Id- anushka@sanskriti.edu.in, Orcid Id- 0009-0002-0147-418X

Abstract

In recent years, conventional pig farming techniques have seen substantial changes; with a growing emphasis on technological innovations to improve production and animal welfare. This paper provides a comprehensive investigation of pig behavior recognition in the framework of conventional pig farming methods. In this research, we observe and evaluate several patterns of pig behavior using computer vision technologies. To observe and understand different parts of pig behavior, the study employs a multi-pronged strategy that includes cutting-edge video surveillance methods. A collection of videos shows 30 pigs engaging in many common behaviors, including sleeping, scratching, eating and drinking. In video data preparation, useful segments are selected and organized into a structured dataset, as well as distorted or incorrect films are filtered. Important details about the pigs' actions over three days are uncovered by the findings. The research investigates the possible advantages of using pig behavior recognition in traditional agricultural systems, including better parenting, early health problem diagnosis and optimized feeding techniques. Furthermore, the ethical implications of using this technology in pig farming are examined, highlighting the need to strike a balance between technical improvements, standards for animal welfare and ethical behavior. This study seeks to promote a sustainable and compassionate method of pig farming that meets the changing needs of society and the agricultural economy. The findings will provide useful insights into the areas of animal welfare and precision livestock production via the recognition of pig behavior.

Keywords: Pigs, behaviors, animal welfare, farming, agricultural system

INTRODUCTION

Pigs are considered to be sociable animals that keep socially structured groups and hierarchical systems. When groups of people move between various living and production stages in industrial agricultural systems, the existing structures of society are upset (1). A new social structure and hostile encounters are created when stranger animals are mixed and this can be detrimental to the well-being and health of the animals. Behavior observation is one of the most crucial criteria in determining a pig's medical assessment, but there are other variables as well (2). The stockperson's assessment, which was time-consuming and arbitrary, was used to make the first assessment of pigs' health. More unbiased and perceptive pig-managing instruments are required (3). Pig production in households has steadily given way to intense large-scale farming in the modern era. The pig business has entered an age of intelligent pig farming with the advancement of big data, surveillance video, sensors and data technology for communication (4). Pork is managed for intelligent pig farming. Pigs are monitored in an automated manner to guarantee that their welfare and standard of life are improved (5). Pigs exhibit a variety of behaviors depending on the circumstances. Pigs perform routine activities including consuming food along with water and removing in a regular environmental setting (6). Breeding and feeding are examples of maternal activities that sows can carry out. Boars are capable of engaging in sexual acts including mounting (7). Pigs can exhibit strange behaviors including aggression, lethargy and tail biting when their living conditions change if they feel uneasy. Pigs that are unwell have been shown to have altered behavior. Consequently, in precision pig farming, monitoring pig behavior is crucial (8). Pig activity has been monitored

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

with the use of technologies including radio frequency identification (RFID), sensors and cameras (9). Sensors translate physical, chemical and biological quantities into electrical quantities by using these technologies. Sensors can monitor various motion characteristics such as direction, speed and acceleration. They have been used to identify pig behaviors such as strolling, running, leaping and sitting (10). Pigs have a wide range of subtle behaviors, which makes it difficult to create reliable and broadly applicable recognition models. This presents a problem in the proper capture and interpretation of small behavioral signals. The study classifies and understands pig behaviors from images coupled with videos, enabling enhanced health management and observation in farming environments.

The study (11) involved extracting temporal and spatial behavioral features from films, employing image structures and visual flow as dual input streams. Two distinct two-stream convolutional network models based on deep learning (DL) were introduced for pig behavior recognition: the Inception architecture and temporal segment networks, both incorporating the extraction of feature networks of residual networks. The research (12) suggested an algorithm for pig mounting behavior identification that takes use of spatial-temporal characteristics in videos. First, a pig detector built on Faster RCNN was used to identify the pig's body, head and tail from the visual frames. Next, three pigs' dimensions distance, overlap area and junction angle are chosen as the spatial characteristics associated with mounting behavior in a single frame. The temporal characteristic was defined as the pace at which these variables change between consecutive frames.

The goal of the research (13) was to create a DL system using videos to identify the eating habits of young pigs and ascertain each pig's feeding schedule individually. Two pig pens were video-filmed for three days as part of the investigation. The initial stage was extracting spatial information using the “convolutional neural network architecture Xception”. They used the long short-term memory architecture to extract spatial-temporal information from these attributes. The findings show that the suggested approach was capable of identifying pigs' eating habits and estimating each pig's feeding period. The study (14) provided a reliable online solution for monitoring and identifying numerous pigs that operate in daytime and infrared (night time) light situations without the need for physical pig identification or manual labelling. Using a new hierarchical data association technique, our solution combines a correlation filter-based tracker with a CNN-based detector. They propose a one-stage prediction network that uses characteristics gathered across numerous layers at various sizes to provide the finder with the optimum speed trade-off. The research (15) developed a deep learning (DL) based system that uses pig detection and tracking in a commercial farm scenario. The method enables them to follow pigs for up to four minutes. The method's tracks can be used to compute behavioral parameters for every single pig, such as total distance travelled, average speed and idle time. The method produces a collection of tracks that can recover the identification in situations when detections are missing and cover a portion of the annotated tracks effectively. The purpose of the paper (16) was to create a depth image analysis technique that automatically recognizes aggressive behaviors in pigs kept in groups. The study included the conduct of two experiments. Eight pigs from three different pens were combined for three days in every investigation, after which eight hours of video were captured a day. Using the 24-hour data from the first experiment, the training set consisted of 883 violent 3 s-units and 883 non-aggressive 3 s-units that were hand-picked. The research (17) enhanced the way behavior varies in male and female 2-month-old pigs in reply to prenatal and postpartum immunological challenges. Pig health and productivity can suffer from the change of behaviors brought by a second antibody challenge and a first immune challenge during gestation. Synthetic poly (I: C) mimics the structure of a mismatched double-stranded RNA and binds to the toll-like receptor 3, inducing pro-inflammatory cytokine release and characteristics similar to those of RNA viruses. Compared to viral infections, the molecular and organism consequences of the viral mimic are temporary because it elicits a brief immune reaction. The research (18) explored whether the early-life rearing environment affected neurocognitive as well as personality traits and presented longitudinal, normative brain development patterns for farmed pigs. As a whole, the pigs' general health and growth performance were unaffected by their early-life raising environment. For absolute brain volume and Fractional Anisotropy (FA) outcomes, there were slight variations in the brain's developmental paths. The paper (19) aimed to partition sticky pig patches in group-pig photos to locate and classify pigs. Pig MS R-CNN has three steps. The feature extraction network generates feature maps from input pictures using a feature pyramid network (FPN) and a residual network with basic layers. After that, the area candidate network generates ROIs from these feature maps. Finally, for each ROI, the pig MS R-CNN uses

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

regression, category analysis along with three masking branches in the main network to locate, categorize and segment pigs. The study (20) provided a novel automated system for pig facial recognition that works wonders with farm-shot images. The offered structure uses deep convolutional neural networks and computer vision methods to strike a compromise between the complex design principles of conventional feature extraction and recognition processes. Specifically, Haar feature-based cascade classifiers are used to identify the pig faces and eyes coupled with a model trained using the categorical cross-entropy loss function that is handled by the Ad delta optimizer was used to conduct face recognition.

ANALYSIS OF PIG BEHAVIOR RECOGNITION IN CONVENTIONAL PIG FARMING

Pig behavior recognition in conventional pig farming entails the systematic observation and study of distinct behavioral patterns shown by pigs in a typical farming context. Farmers and researchers apply new technology, such as computer vision, to monitor and analyze pig activities effectively. These technologies allow the identification of critical indications including lying, scratching, feeding, drinking and contributing to the general well-being and productivity of the pigs. By knowing pig behavior, producers can make educated judgments about feeding schedules, health evaluations and environmental circumstances. This proactive method boosts the effectiveness of standard pig farming operations, assuring the optimum growth and development of the animals while avoiding stress as well as fostering a better agricultural habitat. In essence, pig behavior recognition plays a significant role in upgrading and enhancing the welfare standards of traditional pig farming systems.

Dataset

In this section, the research gathered 30 randomly selected pigs and formed the study's data set to collect videos of the various behaviors in pigs. When the pigs were in the positioning bar 95 for feeding, the faces of the animals were captured from various angles using a standard smart phone. One minute, 30 frames per second (FPS) sampling rate and HD spatial resolution (1980 × 1080 pixels) were applied for every pig. Thus, for every video of every pig, 1,800 images are accessible and we analyzed them for 3 days. The pigs had a variety of natural behaviors, like lying, scratching, feeding as well as drinking and they weren't constantly staring at the camera.

Video Data Pre-processing

The pigs' everyday behaviors were monitored in the recordings that were gathered and uploaded to the computer using a portable phone. The identification process focused on four types of behaviors: lying, scratching, feeding and walking. The four different types of behaviors happened unassisted in the natural pigpen setting. The process of preparing the video recordings began with the selection of the segments that were pertinent to the analysis being done and the organization of those segments into a structured dataset using a standard format. The gathered videos were filtered to exclude videos with invalid images and videos that were distorted due to a lack of lighting. Four different types of pig behaviors were shown in the sample video clips that were chopped and edited. The clip was transformed into a series of video frames after the editing process, each with a frame rate of thirty shots per second and an aspect ratio of 1980 x 1080 pixels. Before the movies were sorted into activity-based groups, they were subjected to a systematic labelling technique in which actions were given names and numbers. We purposely sought video clips from various shooting sessions, recording varied locations of the same activity, to prevent homogeneity in unique samples and to increase the trained network's resilience. By using this route, we hoped to better comprehend different examples of the targeted actions and strengthen the model's flexibility. There was one behavior in every edited clip.

Pig Behaviors Recognition

The next stage after recognizing and monitoring the pigs is to identify their behaviors. For different analytic objectives, we needed a generic activity recognition that could identify several concurrent activities happening in a video. A single pig uses a portion of the feeder to consume food throughout the consuming procedure, which keeps the pig's physique practically unmoving is depicted in figure (1). Because of this, the eating behavior of pigs kept in groups has a consistent motion pattern. This indicates that the pig maintains a stationary

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

body position, with its head confined in each feeding sub-region as it chews and consumes its food. Pigs that aren't eating move their body constantly and don't show the same feeding behavior.

Figure (1). Feeding Process (Source:https://b2030474.smushcdn.com/2030474/wp-content/uploads/2022/03/sowtest.jpg?lossy=1&strip=1&webp=1)

To identify alterations in the collective lying tendencies of pigs kept in profitable farms and correlate these changes with variations in the surrounding temperature. Figure (2) examined the possibility of using a two-dimensional imaging system in agricultural farm settings to identify the lateral and sternal resting postures in pigs. A backdrop subtraction technique was used to separate the pigs from their surroundings. It was the distinct features of each animal that allowed the convex hull and boundary detection in the binary picture to work. They were located by calculating the perimeter and size of each convex hull and border using lateral coordinates.

Figure (2). Position of Lying
(Source:https://i.pinimg.com/736x/67/6a/a9/676aa9e6900b3f23c1c1874f0990e368.jpg)

Scratching is a natural habit that pigs engage in as a method of maintaining their cleanliness and receiving relief from discomfort. Using their snouts or their bodies, pigs can scratch against objects in a confined environment. These surfaces can involve walls or posts figure (3). A kind of grooming activity that manifests itself as friction and shaking is known as scratching. Grooming activity serves the function of smoothing and combing hair, as well as reducing or eliminating sources of external stimulation, such as external parasites, mosquitoes, flies and scales. It is an indication that the health state of a pig is abnormal if the pig's grooming habit becomes less effective.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

Figure (3). Scratching (Source:https://www.visitmysmokies.com/wp-content/uploads/2013/08/Piglet-300x300.jpg)

Pigs are considered to be drinking when they suck on a drinking nipple while water flows into their mouths. Recognizing when the pig's head enters and stays in the drinking area for a particular duration is one automatic recognition function of video-based pig drinking behavior. One theory proposed that one might determine the location of a pig's head by measuring the distance between certain places on its segmented contour; this would allow one to identify its ears. Then, we could tell whether the pig was drinking by looking at the angle at which its head met its drinking nipple, as in figure (4).

Figure (4). Pigs drinking **(Source:**https://agrilifeextension.tamu.edu/wp-content/uploads/2022/05/pigs-hogs-1024x800.jpeg**)**

RESULTS

In this part we analyzed the data for three days to calculate the pigs' behaviors, such as feeding time, scratching, lying and drinking. These behaviors change day by day in their activities.

Feeding time

The loud grunts made by pigs when they gnaw on their meal are very expressive. Fiery and sociable, they can show off their position in society through pleasant rivalry for food. This intriguing social dynamic can be maintained by observing the varying levels of aggression shown by different pigs. After three days of observation, the pigs' feeding behavior showed a significant improvement in feeding efficiency. The pigs' feed consumption rate was 2,200 per second on the first day. On the second day, the pigs' rate of feed consumption increased to 2400 per second. On day three, the pattern persisted and peaked when the pigs showed off their strong eating habits, gobbling up feed at a remarkable pace of 3,000 per second. As a result of their capacity to optimize their nutritional intake over time, the animals' eating pace has been increasing, which indicates an

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

adaptive response and increased passion for feeding. Figure (5) and Table (1) depicts the feeding time in seconds.

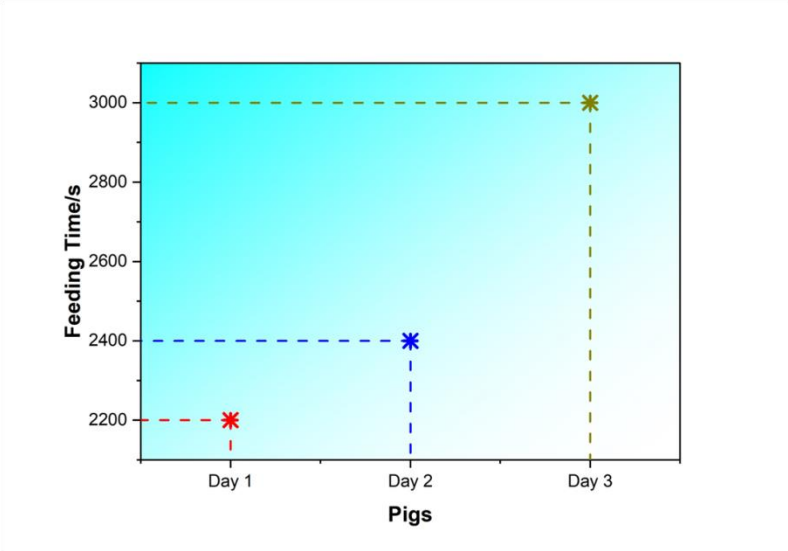

Figure (5). Comparisons of feeding time/s (Source: Author)

Table (1). Numerical Outcomes of feeding time/s (Source: Author)

Pigs	Feeding Time/s
Day 1	2200
Day 2	2400
Day 3	3000

Scratching

Pigs scratch in a different way than other animals; they use their snouts to dig in the ground or scrape on surfaces. They eliminate worms, reduce irritation and keep themselves clean to their innate tendency. Moreover, scratching is an interaction that strengthens bonds between pigs in a group and improves their overall health. Pigs scratched various surfaces in their surroundings at varying frequencies, according to the research. The pigs' scratching frequency on the floor was 0.04, which is a significant indication that they are actively engaging with this surface. A scratching frequency of 0.03 indicates that the pigs were interested in the wood post that was hanging from the ceiling. Wood posts had the greatest scratching frequency, at 0.05, which is rather interesting. According to these results, pigs have different tastes when it comes to scratching surfaces and wood posts seem to be more appealing to their natural behavior. Figure (6) and Table (2) depict the comparisons of scratching materials.

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

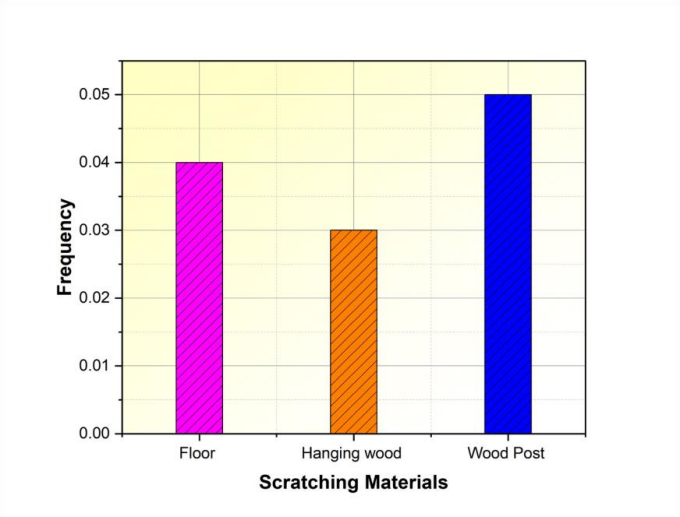

Figure (6). Comparisons of scratching materials (Source: Author)

Table (2). Numerical Outcomes of scratching materials (Source: Author)

Scratching Materials	Frequency
Floor	0.04
Hanging wood	0.03
Wood Post	0.05

Lying

Lying pigs assume sternal or lateral positions. Pigs lay sideways with legs outstretched in the lateral stance. This posture lets them completely stretch out, relaxing them. Pigs lie on their chests with their legs tucked in the sternal position. This attitude implies attentiveness and readiness to rise swiftly. Knowing these lying postures helps to explain pig behavior, welfare and well-being. By observing and understanding these actions, farmers as well as researchers can measure pig health, comfort in different contexts that enhance farming and pig care. Pigs are used in lateral positions rather than sternal positions. Figure (7) and Table (3) depict the comparisons of lying positions.

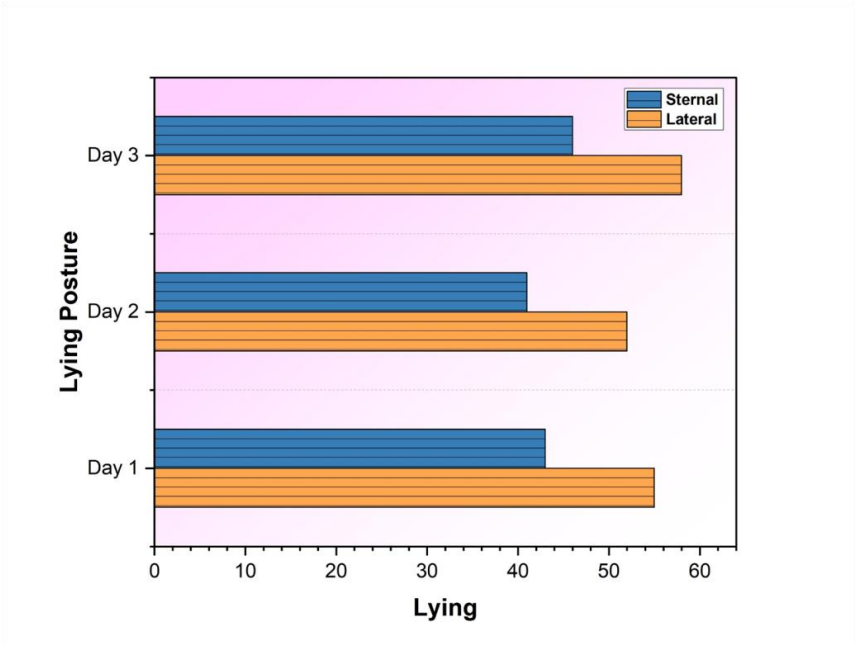

Figure (7). Comparisons of lying positions (Source: Author)

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 24, No. 4 (2023)
http://www.veterinaria.org
Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

Table (3). Numerical Outcomes of lying positions (Source: Author)

Lying Posture	Lateral	Sternal
Day 1	55	43
Day 2	52	41
Day 3	58	46

Drinking

Exciting new information on pig drinking habits has emerged from a three-day research. On different days of the observation, the drinking index, which is the water intake to body weight ratio, changed. A reading of 0.2 for the first day indicates that the pigs drank a modest amount of water about their weight. The index dropped to 0.18 on day two, indicating a little reduction in drinking habit. In contrast, water intake increased from the previous day on the third day, when the index spiked to 0.3. Environmental causes, nutritional changes, or individual pig preferences could explain these three-day drinking behavior shifts, demonstrating how pig behavior is dynamic in response to different circumstances. Figure (8) and Table (4) depict the index of drinking.

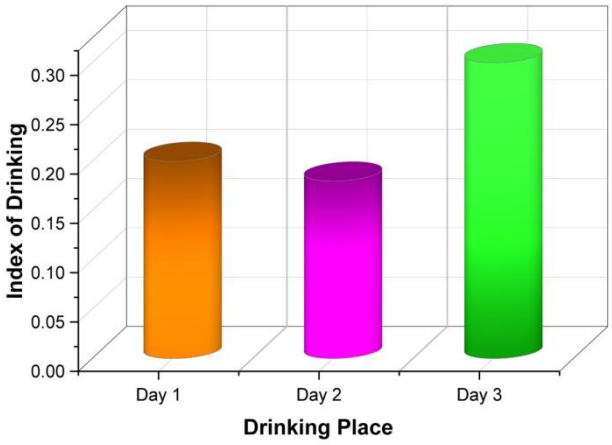

Figure (8). Comparisons of the index of drinking (Source: Author)

Table (4). Numerical Outcomes of the index of drinking (Source: Author)

Drinking Place	Index of Drinking
Day 1	0.2
Day 2	0.18
Day 3	0.3

CONCLUSION

Pig behavior recognition plays a key role in improving conventional pig farming operations by enabling educated decision-making about ambient conditions, feeding schedules and health evaluations, all of which promote higher standards of animal welfare. Pigs engage in a variety of everyday activities, including feeding, scratching, lying and drinking. These habits have been examined in traditional pig farming using cutting-edge technology like computer vision. An in-depth analysis of these behaviors, revealing their dynamics and interactions, was made possible by the use of a dataset that included 30 randomly chosen pigs spread across three days monitored using tailored metrics. Important details about the pigs' actions over three days are uncovered by the findings. It was on the third day that the feeding behavior reached its most efficient point, with feed consumption rates reaching 3,000 per second. It was clear that pigs had preferences for certain materials since their scratching activities differed across surfaces. The lateral position was preferred by the pigs; however

the sternal coupled with lying positions revealed information about their comfort and health. The interesting dynamics of pig drinking patterns revealed a drinking index that varied over three days, indicating a response to personal preferences or environmental cues.

REFERENCES

1. Wutke, M., Heinrich, F., Das, P. P., Lange, A., Gentz, M., Traulsen, I., ...&Gültas, M. (2021). Detecting animal contacts—A deep learning-based pig detection and tracking approach for the quantification of social contacts. Sensors, 21(22), 7512. Doi: 10.3390/s21227512
2. Yang, A., Huang, H., Zheng, B., Li, S., Gan, H., Chen, C., ...&Xue, Y. (2020). An automatic recognition framework for sow daily behaviors based on motion and image analyses. Biosystems Engineering, 192, 56-71. Doi:10.1016/j.biosystemseng.2020.01.016
3. Riekert, M., Klein, A., Adrion, F., Hoffmann, C., &Gallmann, E. (2020). Automatically detecting pig position and posture by 2D camera imaging and deep learning. Computers and Electronics in Agriculture, 174, 105391. Doi:10.1016/j.compag.2020.105391
4. He, B., Gong, W., Yan, X., Zhao, Z., Yang, L. E., Tan, Z., ...&Tu, C. (2021). Viral metagenome-based precision surveillance of pig population at large scale reveals viremic signatures of sample types and the influence of farming management on pig virome. Msystems, 6(3), e00420-21. Doi:10.1128/msystems.00420-21
5. Alameer, A., Kyriazakis, I., &Bacardit, J. (2020). Automated recognition of postures and drinking behavior for the detection of compromised health in pigs. Scientific reports, 10(1), 13665. Doi:10.1038/s41598-020-70688-6
6. Govindasamy, K., Gonmei, C., Singh, N. S., & Singh, N. M. (2022). Thermal stress-related physiological, behavioral, and serum biochemical responses in indigenous pigs adapted to the Eastern Himalayan region. Frontiers in Veterinary Science, 9, 1034635. Doi:10.3389/fvets.2022.1034635
7. Sharma, A., Ahlawat, S., Sharma, R., Arora, R., Singh, K. V., Malik, D., ...&Tantia, M. S. (2023). Tracing the genetic footprints: India's role as a gateway for pig migration and domestication across continents. Animal Biotechnology, 1-7. Doi:10.1080/10495398.2023.2268683
8. Pandey, S., Kalwa, U., Kong, T., Guo, B., Gauger, P. C., Peters, D. J., & Yoon, K. J. (2021). Behavioral monitoring tool for pig farmers: Ear tag sensors, machine intelligence, and technology adoption roadmap. Animals, 11(9), 2665. Doi:10.3390/ani11092665
9. Liu, D., Oczak, M., Maschat, K., Baumgartner, J., Pletzer, B., He, D., & Norton, T. (2020). A computer vision-based method for spatial-temporal action recognition of tail-biting behavior in group-housed pigs. Biosystems Engineering, 195, 27-41. Doi:10.1016/j.biosystemseng.2020.04.007
10. Fleming, S. A., Monaikul, S., Patsavas, A. J., Waworuntu, R. V., Berg, B. M., &Dilger, R. N. (2019). Dietary polydextrose and galactooligosaccharide increase exploratory behavior, improve recognition memory, and alter neurochemistry in the young pig. Nutritional neuroscience, 22(7), 499-512. Doi:10.1080/1028415X.2017.1415280
11. Zhang, K., Li, D., Huang, J., & Chen, Y. (2020). Automated video behavior recognition of pigs using two-stream convolutional networks. Sensors, 20(4), 1085. Doi: 10.3390/s20041085
12. Yang, Q., Xiao, D., &Cai, J. (2021). Pig mounting behavior recognition based on video spatial–temporal features. Biosystems Engineering, 206, 55-66. Doi: 10.1016/j.biosystemseng.2021.03.011
13. Chen, C., Zhu, W., Steibel, J., Siegford, J., Han, J., & Norton, T. (2020). Recognition of the feeding behavior of pigs and determination of the feeding time of each pig by a video-based deep learning method. Computers and Electronics in Agriculture, 176, 105642. Doi: 10.1016/j.compag.2020.105642
14. Zhang, L., Gray, H., Ye, X., Collins, L., &Allinson, N. (2019). Automatic individual pig detection and tracking in pig farms. Sensors, 19(5), 1188. Doi: 10.3390/s19051188
15. Cowton, J., Kyriazakis, I., &Bacardit, J. (2019). Automated individual pig localization, tracking, and behavior metric extraction using deep learning. IEEE Access, 7, 108049-108060. Doi: 10.1109/ACCESS.2019.2933060
16. Chen, C., Zhu, W., Liu, D., Steibel, J., Siegford, J., Wurtz, K., ...& Norton, T. (2019). Detection of aggressive behaviors in pigs using a RealSence depth sensor. Computers and Electronics in Agriculture, 166, 105003. Doi: 10.1016/j.compag.2019.105003

Article Received: 23 October 2023; Revised: 11 November 2023; Accepted: 30 December 2023

17. Rymut, H. E., Bolt, C. R., Caputo, M. P., Houser, A. K., Antonson, A. M., Zimmerman, J. D., ... & Rodriguez-Zas, S. L. (2020). The long-lasting impact of maternal immune activation and interaction with a second immune challenge on pig behavior. Frontiers in Veterinary Science, 7, 561151. Doi: 10.3389/fvets.2020.561151
18. Fil, J. E., Joung, S., Hayes, C. A., &Dilger, R. N. (2021). Influence of rearing environment on longitudinal brain development, object recognition memory, and exploratory behaviors in the domestic pig (Susscrofa). Frontiers in Neuroscience, 318. Doi: 10.3389/fnins.2021.649536
19. Tu, S., Yuan, W., Liang, Y., Wang, F., & Wan, H. (2021). Automatic detection and segmentation for group-housed pigs based on PigMS R-CNN. Sensors, 21(9), 3251. Doi: 10.3390/s21093251
20. Marsot, M., Mei, J., Shan, X., Ye, L., Feng, P., Yan, X., ...& Zhao, Y. (2020). An adaptive pig face recognition approach using Convolutional Neural Networks. computers and Electronics in Agriculture, 173, 105386. Doi:10.1016/j.compag.2020.105386