Computers and Electronics in Agriculture 135 (2017) 4–10

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Using 3D vision camera system to automatically assess the level of inactivity in broiler chickens

A. Aydin

Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Canakkale Onsekiz Mart University, 17020 Canakkale, Turkey

ARTICLE INFO

Article history:
Received 6 January 2016
Received in revised form 24 January 2017
Accepted 28 January 2017

Keywords:
3D vision
Animal welfare
Gait analysis
Lameness

ABSTRACT

In this study, a new and non-invasive method was developed to automatically assess the lameness of broilers. For this aim, images of broiler chickens were recorded by a 3D vision camera, which has a depth sensor as they walked along a test corridor. Afterwards, the image-processing algorithm was applied to detect the number of lying events (NOL) based on the information of the distance between animal and the depth sensor of 3D camera. In addition to that, latency to lie down (LTL) of broilers was detected by 3D camera. Later on, the data obtained by proposed system were compared with visually assessed manual labelling data (reference method) and the relation between these measures and lameness was investigated. 93% of NOL were correctly classified by the proposed 3D vision camera system when compared to manual labelling using a data set collected from 250 broiler chickens. Furthermore, the results showed a significant correlation between NOL and gait score ($R^2 = 0.934$) and a significant negative correlation between LTL and gait score level of broiler chickens ($R^2 = -0.949$). Because of the strong correlations were found between NOL, LTL and gait score level of broilers on the one hand and between the results obtained by 3D system and manual labelling on the other hand, the results indicate that this 3D vision monitoring method can be used as a tool for assessing lameness of broiler chickens.

1. Introduction

Lameness is used to describe a range of injuries of broiler chickens with infective and non-infective origin (Swayne and Halvorson, 2003; Thorp and Dduff, 1988). Furthermore, Vestergaard and Sanotra (1999) concluded that the weight and growth rate were strongly correlated with the occurrence of lameness. In addition, Kestin et al. (2001) showed the effects of accelerated growth rates and heavier body weights on locomotion. Over the last 80 years or so, the slaughter age of a standard fast growing broiler has been decreasing, and market weight has increased. Broilers reach the slaughter weight of 2.5 kg in 40–42 days old because of genetic selections for years, (Narinç et al., 2015). The average slaughter age is 42 days in the EU. In comparison, traditional meat chickens need 12–13 weeks to reach 2.5 kg (EEC, 1991). This very fast growing result a heavy body weight together with not fully-grown skeleton system (Corr et al., 2003). Consequently, this fast growing causes to abnormal 'gait structure'. In some commercial farms, lameness level has been observed on 27.6% of birds with poor locomotion and 3.3% with serious locomotion problems (Knowles et al., 2008). Therefore, activity problems can be painful for broilers and decrease their locomotion while raising other problems, like hock burns and chest soiling (Weeks et al., 2000).

In addition to these problems, broilers are significantly damaged due to skeletal disorders (Cook, 2000). Bradshaw et al. (2002) concluded that the cost of these problems in chickens was predicted to be between 80 and 120 million dollars per year in the USA. Therefore, in literatures, different kinds of methods were developed to detect lameness and improve the health and welfare of broilers. The most common method to detect lameness is visual locomotion scoring (gait scoring) (Kestin et al., 1992), in which the scores are based on the visual observation by a trained expert. An expert's evaluation relies on various parameters such as rolling gaits, walking lame, shaky and lateral body oscillations and manoeuvrability problems.

As an alternative to this method, the latency to lie down test (LTL) was described by Weeks et al. (2002) as the duration of time that broilers could stay standing in shallow water. There was a significant ($P < 0.001$) relationship between LTL and birds' gait scores (Weeks et al., 2002). Nevertheless, to perform this test on commercial broiler farms, requires many times and labour. Thus, Berg and Sanotra (2003) to record the LTL developed a new test. The main difference and advantage of this new test was that the broilers were tested individually and the experimental setup could be transferred between commercial farms. The results of their study

E-mail address: ardaaydin543@hotmail.com

http://dx.doi.org/10.1016/j.compag.2017.01.024
0168-1699/

also showed a significant negative correlation ($P < 0.001$) between gait score and standing time.

However, a visual locomotion scoring method (existing conventional tests) performed by an expert is not useful today because it needs too many time (Viazzi et al., 2014) and the measurements cannot be performed continuously during the lifespan of animals. Consequently, there is no chance of early detection of lameness when these manual evaluation methods are used. Chickens that are mildly lame often remain undiagnosed and not treated until they become severely lame. Furthermore, a significant amount of labour is required, particularly to perform this type of manual test on large commercial farms with more than 100.000 chickens in a broiler house.

As an alternative to these manual evaluation methods, automated monitoring of animal behaviours getting feasible because of the low-cost technology. Different kinds of evaluation methods have been tested in order to develop an automatic lameness detection tool based on behavioural responses, and image analysis (Viazzi et al., 2014). A major advantage of this type of automated behaviour monitoring is that monitoring can be performed with a non-invasive and non-intrusive way during the life of a flock. In addition, it does not involve the biosecurity risk by stopping the need of visiting different broiler farms for lameness analysis (Dawkins et al., 2009). These types of automated methods have also been validated against traditional methods such as manual labelling. However, even the accuracy of measurements taken automatically varies between methods; it can be increased by combining these methods (Rushen et al., 2012). Furthermore, investigating the locomotion behaviour of animals in relation to gait score can serve as a measure for lameness assessment (Aydin et al., 2010).

For example, Leroy et al. (2006) to investigate the hens' behaviour in laboratory, established an image monitoring system. It was concluded in their study that scratching, walking and standing and could be automatically detected (Leroy et al., 2006). In another research, Cangar et al. (2008) studied the activity behaviour of pregnant cows with posture parameters. In their study, a vision system was tested to detect standing, lying, eating and drinking behaviours. In another research, Dawkins et al. (2009) investigated optical flow patterns in broiler chicken flocks. It was concluded in their research that optical flow method could be used for gait scoring on commercial broiler farms. (Dawkins et al., 2009). In 2010, an automated monitoring system was developed by Aydin et al. (2010) to calculate the broilers' activity in relation to gait score. The results of their study showed a significant correlation between gait score (as a measure for lameness) observed by a trained expert and activity recorded by fully automated monitoring tool. Aydin et al. (2010) concluded that image-processing method could obtain an automatic tool to detect broilers' activity in relation to gait score for lameness assessment.

Dawkins et al. (2012) investigated flock behaviour and welfare of chickens by using a camera and optical flow algorithm. In addition to this research, Dawkins et al. (2013) performed another study to reveal the relationship between optical flow and gait score level of broilers. They concluded that their method could be used for the development of new tools to assess the health and welfare of broilers (Dawkins et al., 2012, 2013). In 2015, a new and non-invasive technique was developed by Aydin et al. (2015) to automatically assess the lameness of the birds. For this purpose, the image processing algorithm was applied to detect the number of lying events (NOL) and latency to lie down (LTL) of broiler chickens. 83% of NOL were correctly classified by the automatic 2D monitoring system. It was also concluded that this automatic image processing method could be used as a tool for assessing lameness of broiler chickens (Aydin et al., 2015).

However, up to now, all studies in literatures were based on the recordings of 2D camera systems and manual labelling of the experts. As different from previous studies in literatures, this research represented the first attempt to use of a 3D vision camera system which has a depth sensor to assess the lameness of broiler chickens.

The first objective of this research was to evaluate the use of a 3D vision camera system from top-view to investigate the locomotion behaviours (number of lying events and duration of the latency to lie down) in relation to their gait scores by extracting the back posture of broilers. The second objective of this research was to compare its performance in classifying lame and not lame birds with the conventional gait scoring (manual labelling) approach. The third objective of this study was that it should serve as a new and additional method for developing an automatic lameness monitoring tool for broiler chickens.

By combining this technique with other monitoring systems, it is possible to develop an automated lameness monitoring tool for broiler chickens. As concluded in the study of Rushen et al. (2012), these types of automatic systems may be combined with other monitoring tools such as tracking the activity level and spatial use of broilers (Aydin et al., 2010, 2013), detecting the optical flow patterns of broilers (Dawkins et al., 2012, 2013) and/or monitoring locomotion behaviours of broilers by automated 2D camera system (Aydin et al., 2015) to detect lameness level, health and welfare of broiler chickens with greater accuracy.

2. Materials and methods

2.1. Experimental design and 3D camera

The experimental setup consisted of a wooden test corridor, with dimensions 3.00 m (length) × 1.00 m (width) × 0.50 m (height), a 3D kinect camera and a PC. It was established into the broiler house three days ago before the experiments to preclude the fear of chickens from the new environment (experimental setup/cage). A 3D Kinect camera (Microsoft corp., Redmond, WA) was mounted 2.5 m up to the ground with directly above the centre of the corridor in order to give a top view of the walking area (Fig. 1). The 3D Kinect camera was chosen because it is an affordable and fast camera that is already used in the last four years to develop real-time applications for human health and precision livestock applications. For example, Chang et al. (2011) used it to work on the rehabilitation systems. After a year, the respiratory motion monitoring systems was developed by Xia and Siochi (2012). In 2014, 3D camera was compared with 2D camera system to assess the lameness of dairy cows by automated measurement of animal's back posture (Viazzi et al., 2014).

The field of view of Kinect depth sensor are a 57 horizontal and 43 vertical angular. It can make a recording with 30 frames per second. It was also introduced in the study of Andersen et al. (2012) that the Kinect could obtain a depth image with 640 × 480 pixels at 2 m distance from the object. In the study of PrimeSense (2012) detailed of the depth sensor was described as the depth values were obtained by using an infrared projector that projected a known light pattern to the object and an infrared sensor that detected the reflected light patterns, analysed the distortion and produced the depth image. The camera was attached by an USB port to a computer with quad-core processor of 3.1 GHz each, 16 GB of RAM and Windows 7 installed. OpenNI 1.5 framework was used to record the videos on the computer. Video recordings were performed during five experiments.

2.2. Birds

Five experiments were carried out with 250 male broiler chickens with 35-day-old (Ross 308). The animals were vaccinated

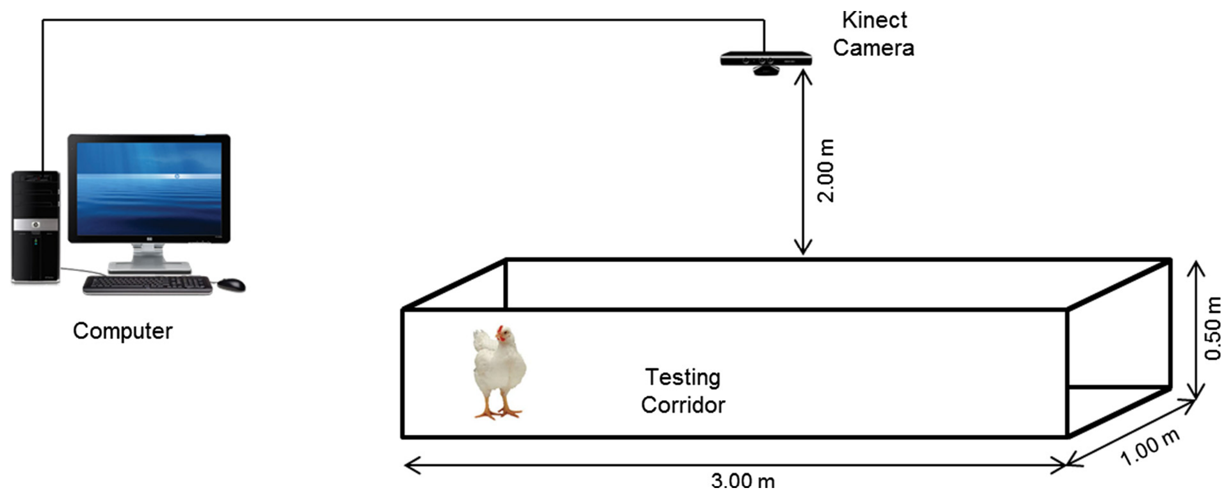

Fig. 1. The test corridor and the video recording equipment.

against for common diseases like Gumboro and Newcastle disease. A starter feed with 23 percent protein and 2890 kcal AMEn/kg was given for the first 9 days. Afterwards, a starter diet with 22 percent protein and 2794 kcal AMEn/kg was given between the 10 and 13 days. Later on, a grower diet with 20 percent protein and 2899 kcal Amen/kg were provided between 14th and 34th days. Finally, a 'finisher' diet was provided with 19 percent protein and 2963 kcal AMEn/kg. Drinking water was ad libitum during experiments. The chickens were gait scored and selected according to the following parameters by an expert using the method developed by Kestin et al. (1992). The rolling gaits, walking lame, shaky and lateral body oscillations and manoeuvrability problems were identified by an expert to define gait score levels of broilers.

GS5 chickens were not used in the experiments, as these birds are unable to walk due to the severity of lameness. In each experiment, fifty broilers were tested with10 broilers belongs to each gait score. For each of the five experiments, the birds were taken from a compartment of 750 and weighed immediately before to testing. In each experiment, a chicken was placed at the start point in the test corridor and a 3D camera recorded video images of the walking area during five minutes while the chicken walked from the start point to the end of the corridor, a distance of 3 m. This procedure was repeated with all 250 chickens.

2.3. Image analysis algorithm (3D)

The algorithm for evaluating the sitting and standing positions of broiler chickens by using a 3D camera was created in Matlab (R2012b, The MathWorks Inc., MA). The flowchart for the proposed 3D monitoring system and classification procedure could be seen in Fig. 2.

2.3.1. Chicken separation

The algorithm for chicken separation was necessary in this experiment since no antenna was installed to trigger the start and stop of the 3D video recordings. A continuous 3D video was recorded and the chickens were automatically separated. The first step in the 3D image processing algorithm thus consisted in detecting when a chicken entered the recording area and in separating the successive bird. Since the Kinect depth sensor calculated the distance between the object and the sensor, the minimal distance was used to separate the broiler chickens. When the chickens walked in the view of the 3D camera, the value of the signal dropped substantially and extremely increased again when the chickens left the view of the 3D camera.

2.3.2. Extraction and classification

The videos recorded from a 3D vision camera system were loaded on Matlab. For each frame the image was segmented by applying a minimal (2000) and maximal (2800) threshold to the depth matrix. All the objects whose area were smaller than 500 pixels (75% the average area of a broiler) were automatically removed by using the function bwareaopen. A certain threshold was defined to extract the chicken from images. A pixel for which the difference was above a fixed threshold was defined as belonging to the shape of the broiler. Then further processing was applied to calculate the contour of the chicken by using the function Bwtraceboundary. Afterwards, regionprops function of the software was used to detect body orientation. The back posture of chicken was represented by the highest pixels around orientation axes. Then, by using polyfit function in Matlab, the back posture of chicken was reconstructed. The highest point in the total body posture of the chickens was used for further calculations. The distance between the highest point in the total body posture of bird and sensor of the 3D camera was used to classify chicken as sitting or standing. The entire flowchart of the image processing was presented in Fig. 2. Latency to lie down (LTL) of broiler chickens was also calculated. Unlike previous studies, in this study any kind of disturbing factor such as water was not used to measure LTL in broiler chickens.

2.3.3. 3D chicken separation

The algorithm of 3D chicken separation was confirmed manually by reviewing the 3D video comparing algorithm output and manual observation. An expert carried out manual observation for lying down events and assessment of the latency to lie down during the experiments.

2.3.4. 3D algorithm execution time

Since the purpose of the 3D vision system was to build a fully automated real-time monitoring system to detect the NOL and LTL of broilers and relate it to lameness, the time of execution was also calculated. The profiling of the 3D code starts after each frame is loaded in the memory of the personal computer and ends when all the features are calculated. A desktop computer with a quad-core processor of 3.00 GHz and 8 GB of RAM was used in the experiments.

2.4. Statistical analysis

The statistical calculations was carried out on 50 video data sets per experiment with 10 data sets belonging to each of the gait

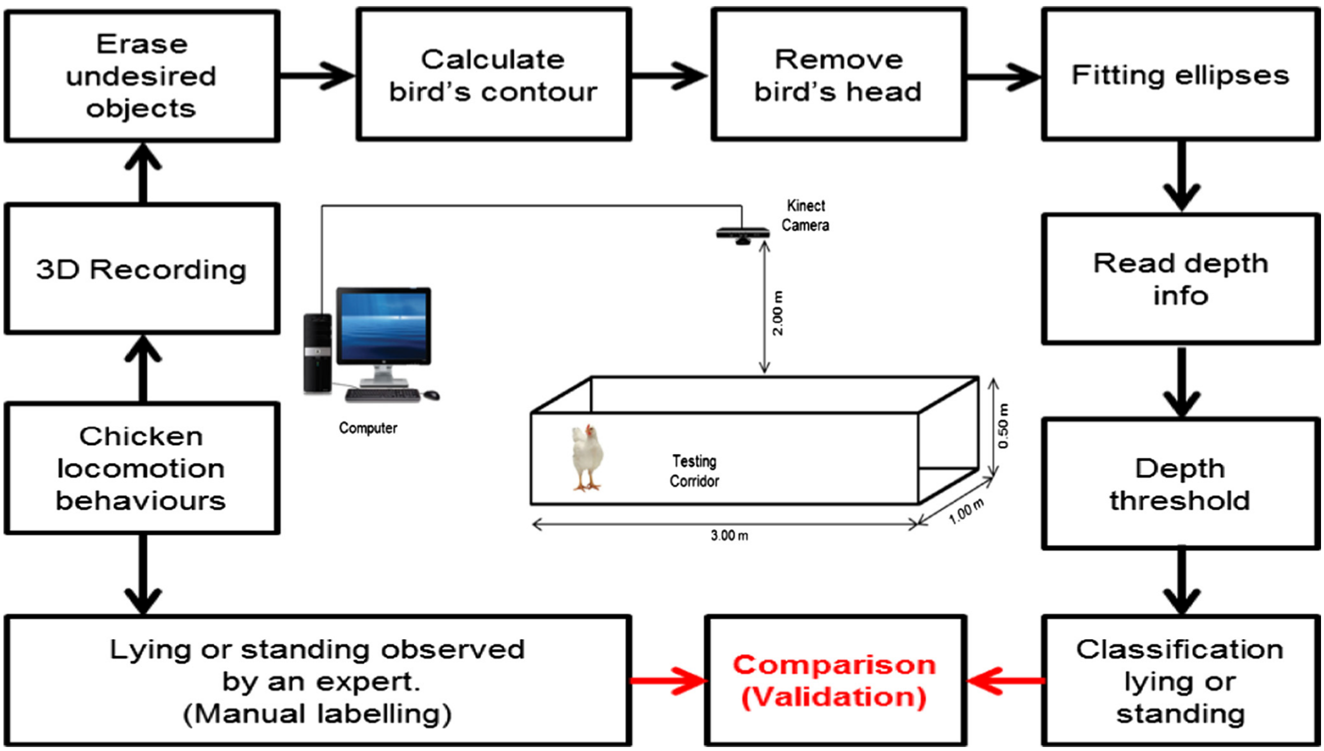

Fig. 2. Flowchart of the image analysis and classification procedure.

score groups. In total, 250 data sets were used to investigate the differences in locomotion behaviours between gait score groups. The Friedman test was used to analyse the effects of gait score on birds' locomotion behaviour. A non-parametric test compares the columns without the row effects. Afterwards, the Dunn test was performed to find the statistical differences among the gait scores. Later on, the results of the proposed system were compared with manual labelling results by performing a linear regression analysis. The calculations were performed using the statistical analysis software (SAS) and Statistics Toolbox of Matlab (The Math Works, Massachusetts, USA).

3. Results

3.1. 3D chicken separation

The manual labelling confirmed that all 250 videos of the algorithm were generated correctly and that the algorithm thus detected all chickens passing under the camera.

3.2. 3D algorithm execution time

The 3D algorithm used the frames where the body of the chicken was fully visible in the image. If the chicken was in the image, it took on average 113 ± 0.01 ms to process the image.

3.3. 3D classification of lying events

Five experiments were carried out with 250 male broilers with the average weight of 2.13 ± 0.14 kg to find a relation between the number of lying events, latency to lie down and the lameness of broiler chickens. The general behaviour of chickens under the test condition was similar with other birds due to the testing corridor was placed into the broiler house two days ago. They were already motivated to join other chickens because of the crowd psychology. Because, there was only one direction for the birds could see and join to the others.

The proposed 3D monitoring tool made it possible to measure the distance between the bird and depth sensor of the camera. When the distance was higher than a specific threshold, the bird's posture was classified as lying. On the other hand, when the distance was lower than a specific threshold, the bird's posture was classified as standing. While the bird was lying, the distance was greater than while standing or walking. Compared with manual labelling, the 3D image analysis method correctly classified total lying events in 250 chickens with an average accuracy of 93 percent. The percentage of correctly classified number of lying events for 250 chickens can be seen in Table 1.

A linear regression test was performed to define the coefficient of determination between the number of lying events obtained by the proposed 3D monitoring system and the number of lying events obtained by manual labelling, which resulted in $R^2 = 0.997$ ($p < 0.05$). Afterwards, the relationship between the latency to lie down (LTL) obtained with the proposed system and LTL obtained by manual labelling was investigated and the coefficient of determination (R^2) was found to be 0.998 ($p < 0.05$). Furthermore, the results of the algorithm were statistically analysed for differences between the different gait score levels. As shown in Table 2, the

Table 1
Correctly classified the number of lying events of broilers using 3D vision monitoring system.

Exp. no	NOL (3D system)	NOL (manual labelling)	Accuracy (%)
1	44	47	93.33
2	44	47	94.49
3	39	42	92.91
4	43	47	92.47
5	45	48	93.48
Mean	43	46	93.34

NOL: Number of lying events.

number of lying events (NOL) in GS2, GS3 and GS4 (mean ± standard deviation) was significantly ($P < 0.05$) higher than in GS0 and GS1 (Fig. 3).

However, there was no significant difference between GS0 and GS1 in terms of the number of lying events (NOL).

3.4. Automatic classification of LTL

The LTL was also evaluated and the results were presented in Table 2. Lame chickens with GS3 and GS4 (mean ± standard deviation) sit down significantly ($P < 0.001$) earlier than those with GS0, GS1 and GS2 (Fig. 4). However, it was found significant differences between all gait scores in terms of latency to lie down.

The range of LTL values recorded were 119–245 s for gait score 0, 55–217 s for gait score 1, 16–135 s for gait score 2, 5–88 s for gait score 3, and 1–26 s for gait score 4. The results also showed a negative correlation ($R^2 = -0.778$ and $P < 0.05$) between NOL and LTL (Fig. 5).

The relationship between lying and gait score is shown in the correlation between NOL, LTL and gait score (Fig. 5). The analysis revealed an important correlation ($R^2 = 0.934$) between NOL and gait score and a strong negative correlation ($R^2 = -0.949$) between LTL and gait score.

4. Discussion

4.1. Assessment of 3D vision monitoring system

Automated vision techniques have the advantage of providing continuous and more frequent information without manipulating the animals with a non-invasive and non-intrusive way. Furthermore, 2D and 3D cameras are going to be cheap based on the developments on the technology. As a consequence, computer vision monitoring systems is increasingly applied in order to obtain valuable information from the animals for various purposes. Even though computer vision monitoring systems could be used to assess lameness of broilers, a reliable and fully automated segmentation of moving broilers as well as the extraction of useful parameters by means of automated monitoring system are difficult to obtain in commercial broiler houses.

However, as illustrated in this study, a 3D vision camera from top view can be useful in the development of a fully automatic measurement of NOL and LTL in relation to gait score as a measure for lameness of broiler chickens. First, it is easier to be applied into existing commercial broiler houses. Therefore, it can help to overcome segmentation problems like shadows, which occur in a 2D view approach. The 3D camera method also proved to be useful for an automated gait score detection system since it reached the NOL and LTL results with less parameter than the 2D camera method. Therefore, it does not need a complex algorithm to calculate the number of lying events to assess the lameness of broiler chickens. Therefore, it can be tested in real time. The average processing time for each frame is 113 ± 0.01 ms. So, the video can be analysed in real time at more than 5 frames per second. Furthermore, this performance can be increased when it was implemented in a programming language other than Matlab. It can also be optimized for speed.

Table 2
NOL and LTL of broiler chickens with different gait scores obtained from proposed 3D monitoring system.

Gait scores	NOL (Mean + Std)	LTL (s) (Mean + Std)
0	02 ± 0.55a	141.20 ± 10.92a
1	03 ± 0.55a	74.80 ± 12.92b
2	05 ± 1.34b	36.00 ± 08.14c
3	12 ± 1.14c	19.57 ± 04.13d
4	21 ± 1.52d	04.60 ± 02.89e

a, b, c Mean ranks, within a column, with no superscript in common differ significantly ($P < 0.05$).
NOL: Number of lying events, LTL: Latency to lie.

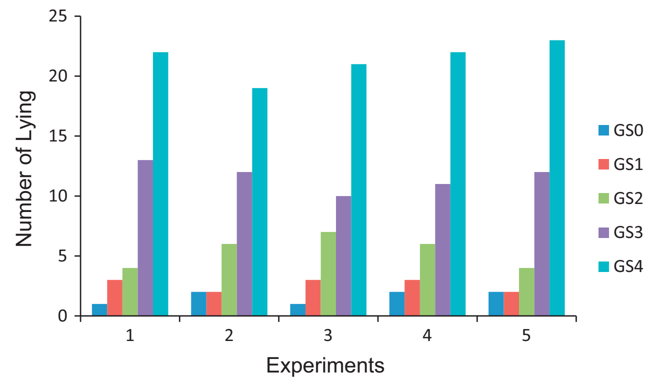

Fig. 3. Number of lying events of Broiler Chickens obtained by the proposed 3D system.

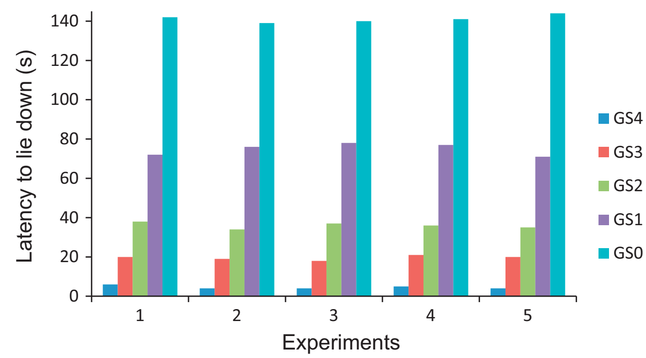

Fig. 4. Latency to lie down of broiler chickens obtained from 3D system.

The most important advantage of the 3D vision approach, not implemented in this manuscript, is multiple animals can be detected even if they are moving together, while a 2D approach relies on single animal. As a consequence, the required time for performing the automated monitoring will be lower to measure the NOL and LTL in relation to gait score of broilers.

As also concluded by Rushen et al. (2012), for more accurate identification of the lameness of broiler chickens, these automatically obtained locomotion information can be combined with other automatic monitoring systems, such as measuring the activity levels of chickens to detect the degree of lameness (Aydin et al., 2010), detecting the optical flow patterns of broilers as suggested by Dawkins et al. (2012, 2013) and monitoring the locomotion behaviours of broilers by automated 2D camera system (Aydin et al., 2015).

One of the most important advantages of these types of automated systems is that monitoring and analysing can be performed non-invasive and non-intrusively during the all life of broilers. The second advantage is that it does not involve the biosecurity risk by stopping the need of visiting different broiler farms for lameness analysis (Dawkins et al., 2009). The additional advantage of taking measurements continuously during the life span of animals increases the likelihood that such tools can also be used for welfare assessment purposes. For example, an early detection system using these combined automated monitoring systems can be set up in a commercial broiler house to detect lameness of broilers before the GS4 and GS5 levels are reached by continuously tracking the different behaviours of the birds.

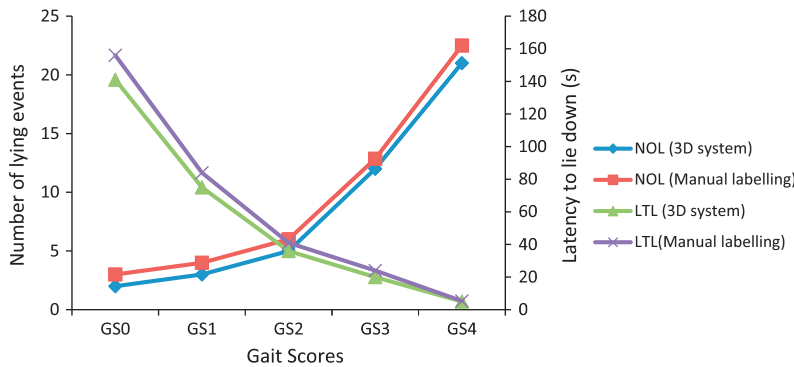

Fig. 5. Correlation between gait scores, number of lying events and LTL measures of broilers and comparison of 3D system output against manual labelling.

However, the results of this research revealed that the 3D monitoring could be used to overcome the accuracy and execution time limitations of a 2D approach by making image segmentation and classification with less parameter. Moreover, the 3D system can be useful for developing an automatic animal monitoring and behaviour analysis system to assess health and welfare of broilers.

4.2. Assessment of NOL in relation to gait score

The locomotion behaviours (number of lying events and latency to lie down) of broilers were detected automatically by the developed 3D vision monitoring system. Afterwards, these behaviours were compared with manual labelling data of experts. It was found that on average 93% of the number of lying events (NOL) could be correctly classified from 250 chickens during the experiments. Furthermore, the results of this research also showed a significant correlation ($R^2 = 0.934$) between gait scores and locomotion behaviours of broiler chickens; this was similar to the results of Weeks et al. (2000) and Aydin et al. (2015). As concluded by Weeks et al. (2000), while the non-lame broilers spent 76% of 23 h as sitting, lame broilers spent 86% of 23 h. The locomotion behaviours of broiler chickens was investigated by Aydin et al. (2015) to assess the lameness of broilers using 2D camera monitoring system. In their research, 83% of NOL events were correctly detected by the 2D camera system. Whereas, in this research 93% of NOL events were correctly detected by the proposed 3D vision monitoring system. It means that the 3D vision monitoring system has the capability to detect NOL events of broilers with 10% more accurately when compared with the 2D camera systems.

In addition to this feature, it is assumed that the 3D vision monitoring system has a shorter execution time than 2D monitoring system, although execution time was not calculated in the study of Aydin et al. (2015). Because in their study, so many parameters such as centre coordinates, rotation angle and the lengths of axis need to be measured to extract the shape of the bird. Furthermore, so many variables such as x-y coordinates, walking trajectory, orientation and the back area of chicken need to be evaluated to decide whether the bird was sitting or standing. Therefore, it was clear that the developed 2D monitoring system (Aydin et al., 2015) needs more time to calculate these parameters and to evaluate these variables to assess the lameness of broiler chickens. Whereas, the decision whether the bird is sitting or standing can be performed by the proposed 3D vision monitoring system which has a depth sensor with a single distance parameter.

4.3. Assessment of LTL in relation to gait score

The latency to lie down of broiler chickens was automatically measured and evaluated by the proposed system. The LTL results obtained by the proposed system were compared with manual labelling data recorded by an expert. Strong correlations were found between the outcome of the proposed 3D vision monitoring system and manual labelling, leading to the conclusion that the system produces reliable results. It was compared with previously published studies in literature and the results showed a similarity with the results of Weeks et al. (2002); the lame birds (GS3 and GS4) sat down significantly ($P < 0.001$) earlier than the sound birds. A significant negative correlation ($R2 = -0.86$, $P < 0.001$) was found by Berg and Sanotra (2003) between LTL and gait score. Similarly, in this study, a strong negative correlation ($R2 = -0.949$) was found between the LTL and gait score level of broilers. Comparable results were also found in the study of Dawkins et al. (2009). They concluded that there was a high and negative correlation between gait scores and the walking time of broilers. Furthermore, the LTL results of this research showed similarity with the results of Aydin et al. (2015).

However, in this study, only the Ross 308 broilers with 35 day old were used in order to produce comparable data. Thus, lying behaviour may be different in other breeds or different ages. The results suggested that this automated 3D vision image processing method had the potential to serve as a tool for monitoring and assessing the number of lying events and latency to lie down of broiler chickens in relation to lameness incidences. On the other hand, using a 3D camera has own limitations. For example, these kinds of cameras were developed for mainly indoor use with artificial lights. Thus, they are very sensitive to natural lights. Therefore, outdoor experiments for other type of animals as cows or goats need to be performed at night or a roof over the camera should be structured to create a shadow on the cameras field of view. However, this is not a practical method to overcome these limitations. Therefore, further studies should test 3D cameras with new technologies and measure the system's performance when applied to multiple animals with different ages under different housing conditions.

5. Conclusions

The focus of this research was to develop a non-invasive and non-intrusive method to assess the lameness of broiler chickens using a 3D vision camera system. To measure the bird's posture and detecting lameness in a broiler house, an algorithm based on 3D camera images, was developed and tested indoor farm conditions on 250 broiler chickens. The number of lying events and the latency to lie down of broilers were correctly classified by the proposed 3D vision monitoring system.

Since strong correlations were found between latency to lie down and gait score level on the one hand and between the number of lying events and gait score level of broiler chickens on the other hand, the results revealed that this automated 3D vision image processing method had the potential to be used as a tool to non-invasively and non-intrusively assess the lameness of broilers. The system has potential but needs to be validated in different field conditions, on different types and ages of chickens and on a larger sample size of broilers. If validation is successful for different types and ages of chickens under different conditions, the 3D vision monitoring technique developed is a promising tool for analysing lying behaviour and indicating lameness in broiler chickens.

References

Andersen, M.R., Jensen, T., Lisouski, P., Mortensen, A.K., Hansen, M.K., Gregersen T., Ahrendt, P., 2012. Kinect Depth Sensor Evaluation for Computer Vision Applications. Electrical and Computer Engineering Technical Report ECE-TR-6.

Aydin, A., Cangar, O., Eren, Ozcan, S., Bahr, C., Berckmans, D., 2010. Application of a fully automatic analysis tool to assess the activity of broiler chickens with different gait scores. Comput. Electron. Agric. 73, 194–199.

Aydin, A., Pluk, A., Leroy, T., Berckmans, D., Bahr, C., 2013. Automatic identification of activity and spatial use of broiler chickens with different gait scores. Trans. ASABE 56 (3), 1123–1132.

Aydin, A., Bahr, C., Berckmans, D., 2015. Automatic classification of measures of lying to assess the lameness of broilers. Anim Welf. 24, 335–343.

Berg, C., Sanotra, G.S., 2003. Can a modified latency-to-lie test be used to validate gait-scoring results in commercial broiler flocks? Anim Welf. 12, 655–659.

Bradshaw, R.H., Kirkden, R.D., Broom, D.M., 2002. Avian Poultry Biol. Rev. 13 (2), 45–103.

Chang, Y., Chen, S., Huang, J., 2011. A kinect-based system for physical rehabilitation: a pilot study for young adults with motor disabilities. Res. Dev. Disabil. 32, 2566–2570.

Commission Regulation (EEC) No 1538/91 introducing detailed rules for implementing Regulation (EEC) No 1906/90 on certain marketing standards for poultry meat. Off. J. L 143, p. 11.

Cangar, O., Leroy, T., Guarino, M., Vranken, E., Fallon, R., Lenehan, J., Meed, J., Berckmans, D., 2008. Automatic real-time monitoring of locomotion and posture behaviour of pregnant cows prior to calving using online image analysis. Comput. Electron. Agric. 64, 53–60.

Cook, M.E., 2000. Skeletal deformities and their causes: introduction. Poultry Sci. 79 (7), 982–984.

Corr, S.A., Gentle, M.J., Mccorquodale, C.C., Bennett, D., 2003. The effect of morphology on walking ability in the modern broiler: a gait analysis study. Anim. Welfare 12 (2), 159–171.

Dawkins, M.S., Lee, H.J., Waitt, C.D., Roberts, S.J., 2009. Optical flow patterns in broiler chicken flocks as automated measures of behaviour and gait. Appl. Animal Behav. Sci. 119 (3–4), 203–209.

Dawkins, M.S., Cain, R., Roberts, S.J., 2012. Optical flow, flock behaviour and chicken welfare. Anim. Behav. 84, 219–223.

Dawkins, M.S., Cain, R., Merelie, K., Roberts, S.J., 2013. In search of the behavioural correlates of optical flow patterns in the automated assessment of broiler chicken welfare. Appl. Animal Behav. Sci. 145, 44–50.

Kestin, S.C., Knowles, T.G., Tinch, A.E., Gregory, N.G., 1992. Prevalence of leg weakness in broiler chickens and its relationship with genotype. Vet. Rec. 131, 190–194.

Kestin, S.C., Gordon, S., Su, G., Sorensen, P., 2001. Relationships in broiler chickens between lameness, live weight, growth rate and age. Vet. Rec. 148 (7), 195–197.

Knowles, T.G., Kestin, S.C., Haslam, S.M., Brown, S.N., Green, L.E., Butterworth, A., Pope, S.J., Pfeiffer, D., Nicol, C.J., 2008. Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLoS ONE 3, 15–45.

Leroy, T., Vranken, E., Van Brecht, A., Struelens, E., Sonck, B., Berckmans, D., 2006. A computer vision method for on-line behavioral quantification of individually caged poultry. Trans. ASABE 49 (3), 795–802.

Narinç, D., Aksoy, T., Önenç, A., İlaslan Çürek, D., 2015. The influence of body weight on carcass and carcass part yields, and some meat quality traits in fast- and slow-growing broiler chickens. Kafkas University 21 (4), 527–534.

PrimeSense, 2012. Primesense 3d Sensor Data Sheet. <http://www.primesense.com/press-room/resources/file/4-primesense-3d-sensordata-sheet?lang=en>.

Rushen, J., Chapinal, N., Passille, A.M., 2012. Automated monitoring of behavioural-based animal welfare indicators. Anim Welf. 21, 339–350.

Swayne, D.E., Halvorson, D.A., 2003. Influenza. In: Diseases of Poultry. Iowa State University Press, Ames, IA, p. 147.

Thorp, B.H., Dduff, S.R.I., 1988. Effect of exercise on the vascular pattern in the bone extremities of broiler fowl. Res. Vet. Sci. 45, 72–77.

Xia, J., Siochi, R.A., 2012. A real-time respiratory motion monitoring system using KINECT: proof of concept. Med. Phys. 39 (5), 2682–2685.

Weeks, C.A., Danbury, T.D., Davies, H.C., Hunt, P., Kestin, S.C., 2000. The behaviour of broiler chickens and its modification by lameness. Appl. Animal Behav. Sci. 67, 111–125.

Weeks, C.A., Knowles, T.G., Gordon, R.G., Kerr, A.E., Peyton, S.T., Tilbrook, N.T., 2002. New method for objectively assessing lameness in broiler chickens. Vet. Rec. 151, 762–764.

Vestergaard, K.S., Sanotra, G.S., 1999. Relationships between leg disorders and changes in the behaviour of broiler chickens. Vet. Rec. 144, 205–209.

Viazzi, S., Bahr, C., Van Hertem, T., Schlageter-Tello, A., Romanini, C.E.B., Halachmi, I., Lokhorst, C., Berckmans, D., 2014. Comparison of a three-dimensional and two-dimensional camera system for automated measurement of back posture in dairy cows. Comput. Electron. Agric. 100, 139–147.