Computers and Electronics in Agriculture 136 (2017) 140–146

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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

Original papers

Development of an early detection system for lameness of broilers using computer vision

A. Aydin

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

ARTICLE INFO

Article history:
Received 8 April 2016
Received in revised form 10 January 2017
Accepted 17 February 2017
Available online 22 March 2017

Keywords:
Body oscillation
Speed
Broilers
Gait score
Lameness
Image analysis

ABSTRACT

Lameness is one of the most important causes of poor welfare in poultry. Previous studies have documented approximately 30% of the chickens were seriously lame. In this research, a novel technique was developed for early detection of lameness in broilers. For this purpose, broiler chickens with five different predefined gait scores were continuously monitored by a digital camera as they walked throughout a test corridor. Then, image analysis algorithm was applied to detect some feature variables (speed, step frequency, step length and the lateral body oscillation) of broilers. Afterwards, a correlation test was performed to define the coefficient of correlation between the feature variables (step frequency, step length, speed and LBO) obtained by the proposed algorithm and the gait score levels of the birds, which respectively resulted in r = 0.831, 0.882 (p < 0.05), 0.844, 0.861. Furthermore, each feature variable was investigated to find statistical differences between gait scores (as a measure of lameness) of broilers. It was performed to assess the effects of gait score on speed, step length, step frequency and lateral body oscillations of the broilers. The results showed that all investigated feature variables were efficacious to detect lameness in broilers starting from GS3. Since correlations were found between the feature variables (step frequency, step length, speed and LBO) obtained by the proposed algorithm and the gait score levels of the birds on the one hand and the statistical differences between gait score levels of broilers on the other hand; the results recommend that this fully-automated detection system has potential to be used as a real-time monitoring tool for early detection of lameness in broilers starting from GS3. However, to define lower gait scores than GS3, either new feature variables like foot curls and wing use should be inserted into the proposed system or this system should be combined with other automatic behaviour analysis tools for early detection of lameness in future research. It is very important to detect lameness at an early stage because it allows farmers and veterinarians to take immediate management actions in time.

1. Introduction

Lameness is a general word which is used for broilers to describe a range of injuries with infective and non-infective source (Thorp and Duff, 1988). In some broiler farms it has been detected that around 27% of broilers showed poor movement and 3% of broilers were nearly unable to move (Knowles et al., 2008). Locomotion problems can be painful for broilers and decrease their mobility while increasing some problems, such as chest soiling (Weeks et al., 2000). The effects of lameness can be seen broilers' ability to run. These can subjectively a "gait score" judged (Kestin et al., 1992; Weeks et al., 2002; Berg and Sanotra, 2003).

Based on Kestin et al. (1992), lameness in broilers was ranked by an expert from gait score zero (GS0) to gait score four (GS4) where GS0 is the normal gait. This scoring method firstly assesses run ability rather than fatigue, with experts already trained to define unsteady movements and problems with manoeuvrability. Another manual scoring method called as "latency to lie down" test (LTL), to assess the solemnity of lameness in broilers was defined by Weeks et al. (2002) as the duration of time that broilers remained standing in shallow water. The results of their research were compared with conventional gait scoring methods. There was a strongly significant ($P < 0.001$) relationship between the LTL and broilers' gait scores (Kestin et al., 1992 and Weeks et al., 2002). A new test was designed by Berg and Sanotra (2003) to record the LTL because of the original testing procedure which makes the test too time-consuming to perform on broiler houses. The major difference and advantage of this test was that the broilers were investigated individually with and the experimental setup could be moved between broiler houses. The results of their

E-mail address: araydin@comu.edu.tr

http://dx.doi.org/10.1016/j.compag.2017.02.019
0168-1699/

research represented a certain negative correlation ($P < 0.001$) between standing time and GS.

On the other hand, it was concluded by Reiter (2002) that broilers have a different locomotor pattern from laying hens. Laying hens place their feet under their bodies' centre of gravity while walking. In contrast to this, broilers move their whole body over the respective supporting leg for each step (Reiter, 2002). This causes the body to oscillate during walking. Lame broilers usually run with bigger lateral body oscillations than healthy birds (Reiter and Bessei, 1997; Reiter, 2002; Corr et al., 2003; Caplen et al., 2012). By using data collected for the description of the locomotor pattern it is possible to recognise even the smallest anomalies of gait (Reiter, 2002). The computer-assisted analysis was able to deduce parameters that allowed gait anomalies to be recognized (Reiter, 2002). For example, kinetic data have been obtained from broilers by using a different kinds of techniques, such as the pedobarograph (Corr et al., 1998), force plate (Corr et al., 2007; Sandilands et al., 2011) and piezoelectric pressure-sensing mat (Naas et al., 2010). In other studies focusing on kinematic analysis, broilers were recorded for the lateral body oscillations with markers attached to the hock, knee and metatarsus (Gatesy and Biewener, 1991; Abourachid, 1991). Nevertheless, it was concluded that there were some disadvantages of this method. For example, markers position can be changed during experiments due to skin displacement. Furthermore, lower accuracy can take place if the broilers diverge from running in a plane parallel to the recording device (Corr et al., 1998). In one of the recent research, some gait parameters were defined by Caplen et al. (2013) to get 3D information from running birds before and after non-steroidal anti-inflammatory drug (NSAID) treatment using a movement recording system. They concluded that their model can be useful to increase our understanding of pain related to the severity of lameness in poultry (Caplen et al., 2013). In another very recent study, the lateral body oscillations were investigated to find the effects of waddle on the ground reaction powers and gait kinematics of turkeys (Stover et al., 2015). Their results showed that increased body weight results in movement changes on the ground reaction power and influence primary mechanics, such as the motion of body (Stover et al., 2015).

Nonetheless, these types of existing tests (manual scoring and gait kinematics) are time-consuming and experiments cannot be performed automatically and continuously with a non-invasive and non-intrusive way. As a consequence, there is no possibility for early detection of lameness when these evaluation methods are used. Additionally, a big amount of manpower is necessary, especially to perform these type of tests on huge broiler houses with more than 50,000 chickens on a farm.

As an alternative to these evaluation methods, the raising availability of low-cost technology currently makes it possible to use image analysis systems for lameness assessment. 2D and 3D camera technology associated with image analysis software, allow animal locomotion to be evaluated to a specific extent. For example, an image processing system was developed by Leroy et al. (2006) to investigate the behaviours of hens in cages. They concluded that walking, standing and scratching of laying hens might be automatically identified. In other recent studies, it was concluded that investigating the movement behaviours of broilers in relation to gait score can serve as a measure for lameness (Aydin et al., 2010, 2013, 2015).

Based on all these literal knowledge, the objective of this research was created as to develop an early detection system with high accuracy for lameness of broilers using computer vision and additional feature variables in Precision Livestock Farming (PLF) approaches. It is very important to detect lameness at an early stage as it allows farmers and veterinarians to take immediate management actions in time.

2. Materials and methods

2.1. Experimental setup and monitoring system

The experimental setup composed of a wooden test corridor, with dimensions 2.40 m (length) × 1.00 m (width) × 0.50 m (height). A video camera, Guppy F036C, was used in the experiments with a C30811KP 8.5 mm lens (ALLIED VISION TECHNOLOGIES GMBH Taschenweg 2a D-07646 Stadtroda, Germany). It was fixed 3.0 m above the ground. It was positioned exactly above the centre of the testing corridor in order to cover the entire experimental setup (Fig. 1). It was also connected to a computer by an IEEE 1394 fire-wire cable. Broilers were recorded by this camera with five frames per second. The resolution of this camera was 1024 × 768 pixels.

Five experiments were carried out with a total of 250 male broilers (Ross 308). The broilers were gait scored and selected before the experiments according to their lameness degree by an expert using the method developed by Kestin et al. (1992). GS5 broilers were not used in the experiments as these broilers cannot walk due to the severity of lameness. For each experiment, in total fifty broilers were chosen with ten broilers from each gait score. For all experiments, the birds were weighed immediately prior to testing. In each experiment, a broiler was placed at the start point in the experimental setup and video images of the experimental setup (all walking area) were recorded during five minutes while the broiler walked from the starting point to the end of the setup with a distance of 2.4 m. This procedure was repeated with all broilers. Overview of chickens used in the experiments can be seen in Table 1. Fluorescent lamps were used in the experiments and the lights were kept on at 20 lx during video recordings.

2.2. Image processing software algorithm

Image processing algorithm was composed of three main sections. The first section was image calibration; in this section the image of the camera was calibrated with the known dimensions of the experimental setup. The second part was image analysis; in this part of the algorithm, the background subtraction method was used for separating broilers shape and the optimal value of the shape parameters (x, y, α, a, b) for each image was labelled for future calculations. In the last part of the algorithm, shape parameters were used to calculate the feature variables of the broilers. All these sections about the image processing software algorithm will be detailed in the following parts of the manuscript.

2.2.1. Image calibration

Before the experiments, the image of the camera was calibrated with the known dimensions of the experimental setup (2.4 m × 1 m). The pixels areas in the image were transformed to units of cm^2 on the experimental setup. These distances were measured in the image with the pixels units, then the positions within the experimental setup was calculated as $f = 0.47$ cm per pixel using a linear factor related to image coordinates. Thus, the interval between two points, one pixel apart was 0.47 cm on the experimental setup and the other pixels area was calculated as $f^2 = 0.22\ cm^2$ on the experimental setup.

2.2.2. Image analysis

The background subtraction method was used for the separation of the broilers shape. This method was chosen because the camera setup was fixed. Therefore the background remained stable over time. Separation was made by extracting the empty setups background image from each recorded image of the setup containing a broiler. When the difference was bigger than a certain thresh-