

Article

Movement analysis to predict broiler walking ability

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Abstract: The genetic development of commercial broiler led to body misconfiguration and consequent walking disabilities, mainly at the slaughter age. The present study aimed to identify broiler locomotion ability using image analysis automatically. A total of 40 broiler 40 d-old were placed to walk on a specially built runway, and their locomotion was recorded. An image segmentation algorithm was developed, and the coordinates of the bird's center of mass were extracted from the segmented images for each frame analyzed, and the Unrest Index (UI) was applied. We calculated the center of mass's movement of the broiler walking's lateral images, therefore, capturing the bird's displacement speed in the onward direction. Results indicated that broiler speed on the runway tends to decrease with the increase of the gait score. The locomotion did not differ between males or females. The proposed algorithm was efficient if predicting the broiler gait score based on their displacement speed.

Keywords: computing image analysis; gait score; unrest index;

1. Introduction

Broilers are the fastest-growing and cheapest animal protein source among farmed species. Broiler meat is usually affordable, low in fat, and faces few cultural barriers. The largest broiler meat producer countries are the USA (20.2 10⁶ metric t/year), Brazil (13.8 10⁶ metric t/year), and China (14.6 10⁶ metric t/year). The world production of broiler meat reached 100.8 10⁶ metric t/year in 2020 [1].

Artificial selection in the domestic chicken (*Gallus gallus domesticus*) has led to derived morphology, physiology, and behavior different from its red jungle fowl ancestor [2-3]. Since the broiler configuration changed, so did the center of body mass, implicating locomotor issues and lack of well-being in intensive production [4]. When a bipedal animal (including broilers) walks, it generates a specific force over the floor that is a function of its weight and the way it lays the claws on the ground. The movement during locomotion changes the center of mass of birds, changing both kinetic (e.g., ground reaction forces) and kinematic data (e.g., stance and stride duration) [5]. During walking, the leg acts as a solid strut so that the body's center of mass rises over the leg reaches a maximum in the middle of the stance phase, while the opposite leg swings forward. Walking gaits are efficient because there is an alternating transfer between the body's potential and kinetic energy within each stride. Physical abilities influence locomotion in broilers, and healthy broilers walk freely inside the house [6,7].

According to Dawkins (2017) [8], the most straightforward definition of 'good welfare' is that the animal is healthy and has what it wants and needs. Therefore, when lameness denies the animal possibility to access feed and water or lead to pain, it is an

important sign of lack of welfare [9]. Locomotor issues also impact broiler performance and may be associated with high flock mortality [10].

Quantification of gait can be made by calculating kinematic parameters such as linear walking velocity, acceleration, stride and step length, and angular parameters (velocities, accelerations), and range of motion of joints. Observational gait analysis allows the comparison among sample populations [4, 11]. The observational gait scoring method developed by Kestin et al. (1992) [12] is possibly the most widely adopted worldwide. In this approach, the bird's walking ability is graded between 0 (perfect walking) to 5 (unable to move).

With the decline in labor in rural areas, broiler on-farm tasks' automation is a necessary change. In current literature, there are initiatives for the development of new algorithms to provide the basis of processes automation built on broiler behavioral patterns [13-16]. However, the broiler gait automatic assessment is still a challenge since just partial answers were reached [17-20].

This study aimed to identify broiler walking ability and estimate the gait score based on the recorded images and movement analysis.

2. Materials and Methods

The present study is part of a large project that investigates the automatic assessment of broiler welfare. The field experiment was approved by the UFGD Animal Ethics Committee (Protocol n. 030/2013).

2.1. Data recording

A total of 300 1-day old chicks mixed-sex (Cobb®508) were standard-reared in an experimental house. When the broilers reached 40 days old, 20 birds of each group (2 genres) were randomly selected (totaling 40 birds). An experienced animal scientist assessed each broiler gait using the 0 to 5 scoring system [21]. The gait score (GS) 0 (GS0) was given to sound birds. The gait score 1 (GS1) meant the broiler had an identifiable gait defect but looked with less mobility than the sound birds. The selection criterion of gait score 2 (GS2) was that the bird showed a visible locomotor defect that had little impact on its mobility [22]. The gait score 3 (GS3) were broilers with mild lameness with identified gait deficiencies that affected their capacity to move. The lame broiler had a gait score 4 (GS4). The gait score 5 (GS5) indicates severely lame birds. Broilers with GS5 were not selected to be tested as they would have enormous difficulty walking.

After carefully selecting the birds, they were separated by GS to represent the range of scores, and a video recording was made. The objective was to study the broilers, which provide a clear description of the pre-defined scores. The birds could choose their speed, and both velocity and acceleration were calculated retrospectively at the analysis level. The videos were taken in a specially built platform 1 m long and 0.30 m wide, with a flat surface covered with 8 cm of litter substrate (rice hulls), the same material the broilers had in the rearing house. The video recording background was a blue wall, placed to provide proper contrast with the birds. The platform was closed with a transparent acrylic wall 50 cm high. The birds were stimulated to walk on the runway, and the video was recorded in .mp4 format with the speed of 30 frames/s (FPS) using a video camera (Sony® Handycam Memory Flash PJ200, Sony Corporation, Tokyo, Japan) equipped with special lenses to correct the parallax effect (Lens Carl Zeiss® Vario-Tessar® Carl Zeiss, Oberkochen, Germany) with 2.8 mm opening. The video camera was fixed on a tripod at a 1 m distance from the platform directly facing the runway. Such a studio set-up was previously described in [19]. The overall schematic of the study is shown in Figure 1.

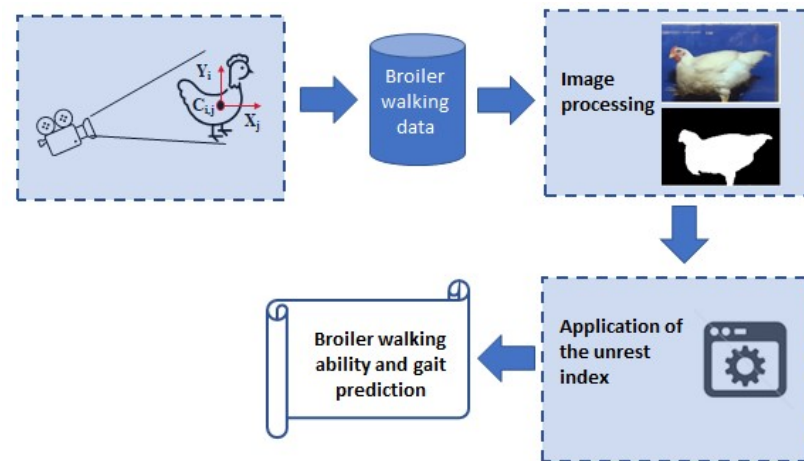


Figure 1. Schematic of the study to predict broiler walking ability.

2.2. Image processing

The videos were recorded with a camera positioned on the birds' side, and it was restricted to walking on a delimited path. A blue background was used to improve the bird's contrast in the scenes, as shown in Figure 2. The recordings had variable durations, according to the difficulty of birds walk on the platform.

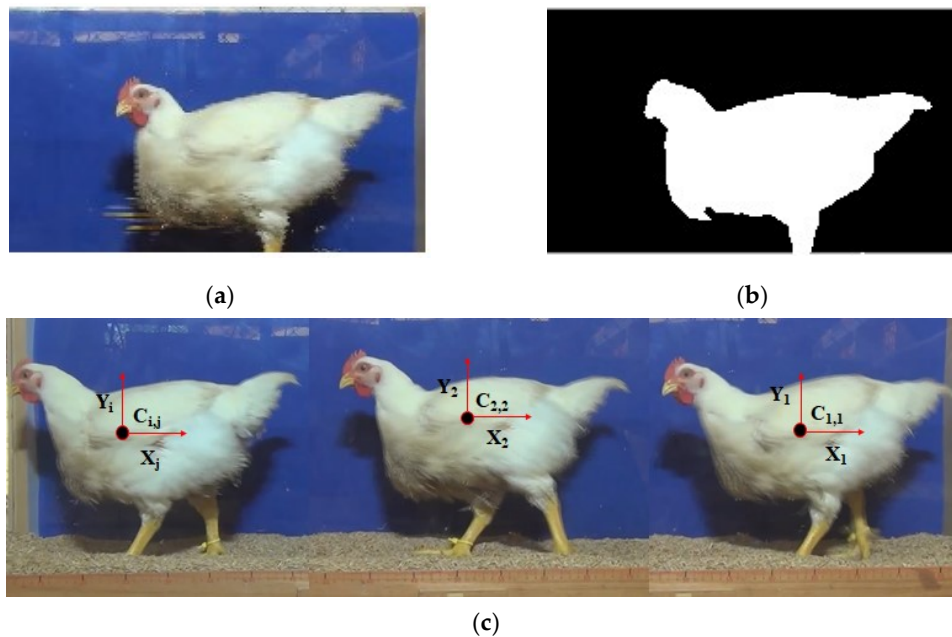


Figure 2. Original (a) and segmented (a) images of the broiler walking the defined path to assess the gait score and the displacement of the center of mass (c). C_{ij} is the center of mass in the frame ij .

An image segmentation algorithm was developed, and the coordinates of the bird's center of mass were extracted from the segmented images for each frame analyzed, and the Unrest Index (UI) proposed by Del Vale (2020) [23] was applied which is measured in pixels. However, to transform the Unrest Index values in cm, a proportionality factor was applied to the formula described in [23] based on the camera's distance and the CCD sensor's resolution (a function of the number of pixels and their size relative to the projected image). The Equations (1 and 2) adopted in the present study are described below.

$$UI_{(i,i-1)} = k \cdot [\max\{dH(F_{(i)}, F_{(i-1)}), dH(F_{(i-1)}, F_{(i)})\}] \quad (1)$$

where $UI_{(i,i-1)}$ is the poultry bird Unrest Index between two sequential frames, k is the proportionality factor defined in Eq. (2).

$$k = \frac{2H \tan(\alpha/2)}{w} \quad (2)$$

where H = the distance from the recording camera to the moving target (1 m), α = the camera lens opening angle (0.5), and w = the sensor CCD horizontal resolution (1920 px).

When applied to videos with only one bird, the Unrest Index corresponds precisely to the path that the bird's center of mass traveled between two frames under analysis, but in both directions (x , y). The index also captures the vertical movements of moving up and down (during the broiler walking, Fig. 2c). As the index is calculated between frames with a 1 s window, the calculated UI corresponds to the gait speed in cm/s. As the difficulties of assessing the broiler's gait score when recording the videos were already known, statistical analysis was applied to verify the Unrest Index's explanatory power, comparing it with the predetermined gait classification in the evaluation of the broiler gait score.

3. Results

Results are presented following the data acquisition. First, we present the video information from the broilers' locomotion ability with a determined gait score. Second, we introduce the results from the video analysis applying the UI.

3.1. Unrest index

Figure 3 shows the evolution of the movement speed of the birds calculated from the UI. This speed expresses the center of mass's movement in the x and y -axis of the broiler walking's lateral images, therefore, capturing the bird's displacement speed in the on-ward direction.

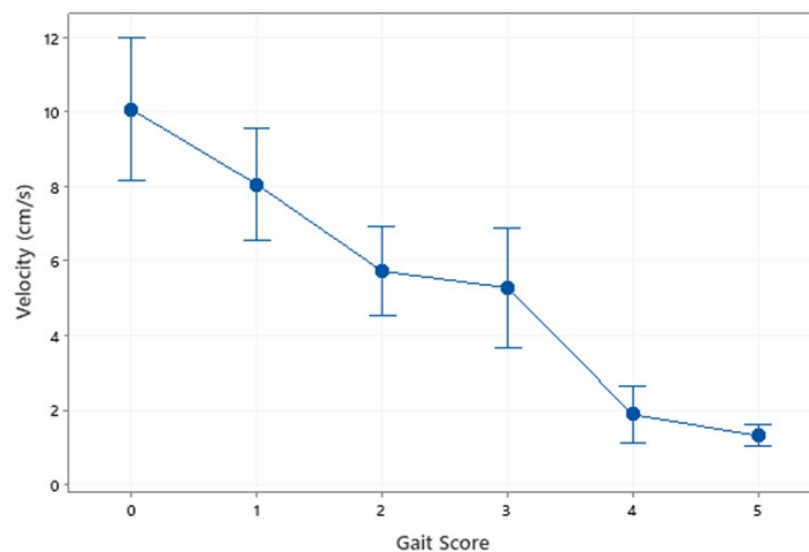


Figure 3. Broiler displacement velocity values of the Unrest Index with known gait scores.

It seems that the broiler displacement velocity calculated from the Unrest Index indicates that there is a tendency to decrease with the increase of the gait score. The

ANOVA test was applied to the data, and there was a significant difference ($p < 0.05$) in the velocity between the GS recorded. Table 1 shows the test of means applied to the displacement velocity measured in each gait score. It appears that the UI was only able to differentiate the birds' extreme and intermediate GS.

Table 1. Differences between the average velocity (cm/s) observed in the broiler footage with different known gait scores.

Gait Score	N	Mean
0	29	10.0580a
1	40	8.4469a
2	52	5.9642b
3	46	4.8037b
4	56	2.2732c
5	48	1.2861c

Different letters indicate a significant difference by the Tukey test ($p < 0.05$). N=number of sequential images.

The gait score did not differ between males and females (ANOVA, $p > 0.05$), with both genres having a decrease in gait speed as the GS increased (Figure 4).

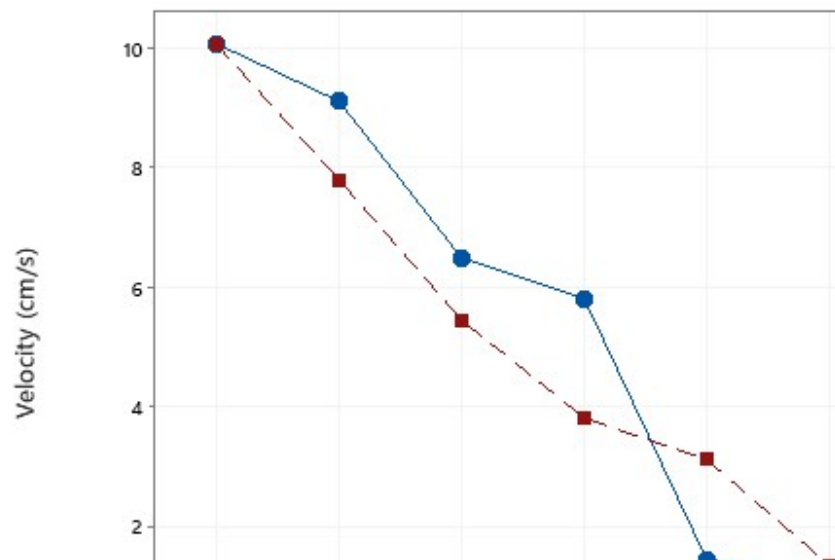


Figure 4. Broiler velocity according to the gait score and the genre.

4. Discussion

The broilers' walking velocity was evaluated by the Unrest index, a new automatic method. It grouped the gait scores in three levels (initial, intermediate, and final), indicating that even if this grouping occurs, the continuous method of evaluating the agitation index in gait can be used for early detection of initial levels (birds with higher speed of movement) and support for birds of the most severe levels of locomotion (birds with a lower velocity of displacement). Other studies have evaluated the birds' gait score using automatic methods and an activity index [11,18,24,25]. Aydin et al. (2010) [24] investigated activity levels of 32-day-old mixed-broiler chickens with different gait scores, using gait scores from 0 to 5, using an automatic image monitoring system under laboratory conditions. The authors compared the relationship between the scores quantified by humans and by the automatic image monitoring system and obtained a significant relationship for both methods.

Detailing these results, birds with gait score 3 (GS3) showed more activities than the other scores in both methods and also did not find differences between GS0, GS1, and

GS2, whereas scores 4 (GS4) and 5 (GS5) had lower activities [24]. As in the present study, the highest scores (GS4 and GS5) had lower displacement velocities due to the low rate of agitation. Aydin (2017) [18] developed an automatic detection system for lameness in broilers. The 39 d-old male chickens were gait evaluated and selected before the experiments according to the degree of locomotion issues (GS0 to GS4, GS5 was not included due to lameness severity). Birds were continuously monitored by a digital camera that was analyzed by an algorithm to detect speed, step frequency, step length, and lateral body sway, including the application of a correlation test between the variables and the birds' gait score levels. Their results show that the characteristics were efficient only in detecting lameness from GS3 and the step length of a chicken with lameness (GS4) was shorter than the step length of healthy chicken (GS1), also indicating a lower speed in regarding the severity of lameness.

The UI also measures the bird's movement; however, it does so by changing pixels representing the animal between consecutive images according to the movement's intensity. Through image processing, a percentage of the animal's pixels in motion is defined concerning the total number of pixels in the image, and the precision may show temporal and spatial variations as it is affected by the sampling time interval [24-25]. Compared to the UI method used in this study, the advantage is that even if the bird moves around the center of mass, for example, in a rotation movement in which there is no variation in the center of mass, this measure will still return a value greater than zero, which can be applied to flocks or individual birds.

In studies using optical flow, the ability to detect animal movements in a sequence of frames considering that the intensity of the pixels remains constant over time and a neighborhood of pixels that move together used this method to assess behavior and broiler chickens gait [13,17,26]. Dawkins et al. (2009) [13] tested mass movements detected by changes in the optical flow of chickens (male and female) from 32 to 35 days of age using a score of three points (GS0 to GS2). Their results indicated higher mean flows for more activity (walking and step rate), with a significant correlation between step rates and optical flow variance. There was a significant correlation between behavior and gait scores. However, the correlation was negative for the lowest gait levels (GS0, GS1), which the stride rate can explain, and the time broilers spent walking [13].

Dawkins et al. (2012) [14] analyzed mixed-genre broilers' behavior (1-35 days old) using a combination of low-cost camera and statistical analysis of optical flow patterns. The results indicated that neither the average flow rate nor the variance was significantly correlated with the gait score, justified by the authors by the narrow range of gait scores evaluated in the study, thus reducing the birds' movement analysis parameters.

In the present study, the broiler's movement did not differ concerning genre. The genre differences in gait can be linked to the measured differences in adult birds' morphology [3,27]. According to the authors, in females, the emphasis is on reproduction, bringing forward the onset of egg-laying, which is continuous throughout their lives, rather than occurring only in breeding seasons. On the other hand, male birds have greater muscle, bone, heart, and blood masses than mature females. However, these distinct dysmorphisms appear when birds are roughly 4–5 months old [2,27]. In commercial broiler production, the genre-mixed flock is slaughtered nearly 40-45 d-old, when still did not reach sexual maturity and, therefore, do not show dysmorphism differences, as in the current study, the displacement velocity did not differ between male and female.

5. Conclusions

The Unrest index was efficient if predicting the broiler gait score based on their velocity of displacement. Since the birds' movement effectively predicts their displacement, we infer that the birds are moving appropriately to feeder and drinker and, therefore, assessing feed and water, which is an essential well-being condition.

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