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Weight prediction of broiler chickens using 3D computer vision

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ABSTRACT

In modern broiler houses, the broilers are traditionally weighed using automatic electronic platform weighers that the broilers have to visit voluntarily. Heavy broilers may avoid the weigher. Camera-based weighing systems have the potential of weighing a wider variety of broilers that would avoid a platform weigher which may also include ill birds. In the current study, a fully-automatic 3D camera-based weighing system for broilers have been developed and evaluated in a commercial production environment. Specifically, a low-cost 3D camera (Kinect) that directly returned a depth image was employed. The camera was robust to the changing light conditions of the broiler house as it contained its own infrared light source.

A newly developed image processing algorithm is proposed. The algorithm first segmented the image with a range-based watershed algorithm, then extracted twelve different weight descriptors and, finally, predicted the individual broiler weights using a Bayesian Artificial Neural Network. Four other models for weight prediction were also evaluated.

The system were tested in a commercial broiler house with 48,000 broilers (Ross 308) during the last 20 days of the breeding period. A traditional platform weigher was used to estimate the reference weights. An average relative mean error of 7.8% between the predicted weights and the reference weights is achieved on a separate test set with 83 broilers in approximately 13,000 manually annotated images. The errors were generally larger in the end of the rearing period as the broiler density increased. The absolute errors were in the range of 20–100 g in the first half of the period and 50–250 g in the last half. The system could be the stepping stone for a wide variety of additional camera-based measurements in the commercial broiler pen, such as activity analysis and health alerts.

1. Introduction

In 2025 the world population is expected to exceed 8 billion people, and by 2050 it is expected to hit 9.6 billion (Malik, 2013). This 35% increase in world population over the next 35 years necessitates effective livestock production methods. The current study focuses on broiler chickens which is one of the main food sources with an estimated annual global production of more than 90 million tonnes of meat (Faostat, 2012). The weight of the broilers throughout the rearing period is one of the key metrics in assessing the effectiveness of the production by comparing consumed feed with measured broiler weight. The daily mean weight is used as metric in common practice. A deviation from the expected weight can further indicate ill thrift, diseases and vitality issues (Lott et al., 1982; Flood et al., 1992). Currently, the farm manager can choose to weigh a sample of the broilers manually or use an automatic platform weighing system. Manual weighing generally requires a lot of manual labor and is therefore time consuming and it is also stressful for the birds (Turner et al., 1983; Doyle and Leeson, 1989). With the automatic platform weighing systems, the birds that stand or sit on the platform will be weighed to give daily mean weights automatically. These systems are less stressful for the broilers, since there are no intruders chasing and constraining them. However, there is the tendency that the heavier broilers will visit the weigher less frequently than others in the final weeks and, hence, underestimate the true weight (Newberry et al., 1985; Chedad et al., 2003; Blokhuis et al., 1988).

In the current study, a non-intrusive camera-based system is investigated. The system does not require the broilers to voluntarily step onto the weigher and therefore weighed all birds in the field of view of the camera. Besides, the camera may cover a larger area of the floor than a traditional platform weigher. With an area of 1 m^2 the weight of several birds may be estimated to get more accurate mean weight estimates and weight distributions. Potentially, it may also weigh birds that would avoid a platform weigher due to e.g. illness or large weight. Camera-based systems

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are not commercially available for broiler weighing, but do exist for e.g. pig weighing (AgroFarm, 2015). Camera-based pig weighing has received a lot of attention (Schofield, 1990; Kashiha et al., 2014), but also e.g. cows and sheep have been measured and weighed using cameras (Tasdemir et al., 2011; Menesatti et al., 2014). The basic assumption of camera-based weighing is a close relation between animal volume and weight which may often be realistic in production scenarios. Further, many studies assume that the weight is directly related to the visible occupied area of the animal as seen from the camera (Kashiha et al., 2014; Mollah et al., 2010). Other approaches use specific biometric measures such as head–tail length or shoulder-shoulder distance (Wang et al., 2008).

One of the few examples of camera-based broiler weighing is De Wet et al. (2003) which investigated surface area and periphery of the broilers as weight descriptors. They achieved an average relative error on the predicted weights of 11% from the surface area. Mollah et al. (2010) used the contour area to predict weight during the 42 day rearing period with comparable precision. These proof-of-concept studies suggest that camera-based weighing of broilers is indeed feasible.

There has been other uses of camera-based techniques than weight prediction on poultry. For instance, segmentation and tracking algorithms were developed by Sergeant et al. (1998) and Leroy et al. (2006) with the purpose of analyzing the behavior of broilers and laying hens, respectively. In the recent work by Nakarmi et al. (2014), algorithms were developed for a 3D camera together with RFID tags to track laying hens. Dawkins et al. (2013) investigated optical flow algorithms for automatic irregularity detection in the broiler flock and Kristensen and Cornou (2011) explored motion detection algorithms for activity pattern analysis.

In the current work, an automatic camera-based system for use in commercial production scenarios with free-ranging broilers in the pen was developed. Due to heavily controlled day and night cycles, the vision system was designed to perform equally well under varying light conditions. The approach was to use the low-cost Kinect 3D camera which satisfied these criteria. A weighing system that use this 3D information to estimate the weight of free-ranging broilers was developed and the system performance was evaluated against a commercial platform weigher.

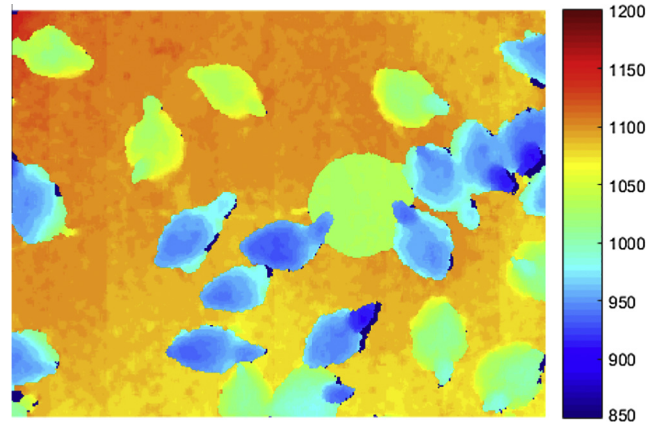

Fig. 1. Depth image taken with the Kinect camera. The different colors directly show the distance from the camera to a position in the image and can therefore be seen as a 3D representation. The scale bar shows the distance in milimeters from the Kinect camera to an object. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

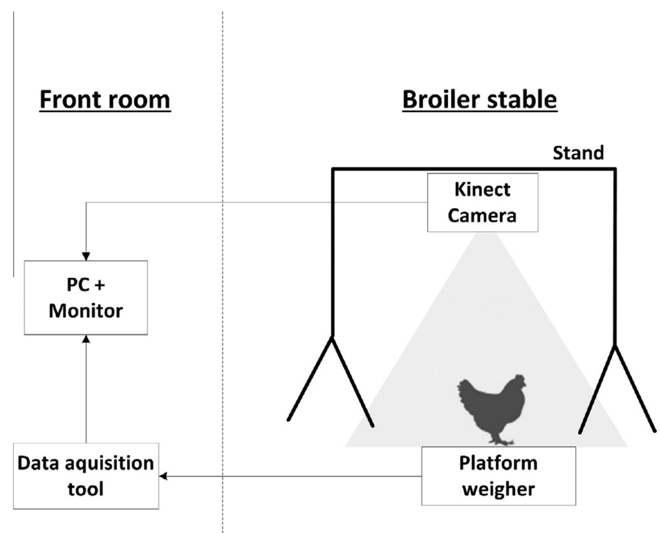

Fig. 2. Overview of the experimental arrangement which consists of a Kinect camera and platform weigher inside the broiler stable and data acquisition in the front room.

2. Experimental setup and data set

2.1. Experimental arrangement and equipment

The current study focused on 3D range cameras and in particular the Kinect camera which is a low-cost consumer product that could realistically be used in commercial automatic weighing systems. The Kinect camera directly records a depth image (640 × 480 px) as seen in Fig. 1. It has been used in many computer vision systems previously due to the its ability to record 3D information, but also its robustness to visible lighting conditions and ease of image segmentation (Andersen et al., 2012). The Kinect itself emits an infrared pattern to estimate depth which means that it is not disturbed by the changes in the visible light that can happen in a broiler house and will work even in complete darkness. The infrared pattern is generated using a laser with a wavelength of 830 nm, which is located well above the spectral sensitivity of the broilers (350–750 nm) (OpenKinect, 2015; Lewis and Gous, 2009). This left the broilers unaffected by the IR pattern emitted by the Kinect and it did therefore not disturb their day and night cycles.

A overview of the experimental arrangement is illustrated in Fig. 2. It consisted of the Kinect camera together with a traditional platform weigher (DOL 94-10 from SKOV A/S) that was used to give a reference weight. Besides, a data acquisition tool (Analog Discovery from Digilent Inc.) and a standard PC were located in the front room. The Kinect camera was mounted in an aluminum box to protect it from the dust within the rearing house and attached to a metal stand 110 cm above the floor covering an area of 1.20 × 0.87 m^2 on the ground. The platform weigher was glued to the floor below the camera. The frame rate of the Kinect camera was 15 FPS, while the sample rate of the weigher was 25 Hz.

The experiment was carried out in a commercial production-environment in a typical rearing house of the region (Broenderslev, Denmark, March 2014). The fully-isolated house contained approximately 48,000 Ross 308 broiler chickens. The house measured 22 × 125 m^2 with 50% wood-shavings and 50% sphagnum as litter. The photoperiodic regime consisted of two dark periods from 00:00 to 4:00 and from 12:00 to 14:00. During the light periods, light intensity was approximately 25 lx. The temperature was 34 °C from day 1 and decreased to 18 °C on the final day. The humidity was at 50% at day 1 and increased to 77% at the final day. The ventilation system was a negative pressure system with ventilators in both the ceiling and the rear wall. Fig. 3 illustrates