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Research paper

Development of a temperature measurement system for a broiler flock with thermal imaging

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ABSTRACT

Broiler body temperature is an important indicator of both a broiler's response to its environment and its overall health. This study used an infrared thermal camera to capture the thermal images of a broiler flock in a broiler house and then analyzed the temperatures of the broiler flock by image processing. Given the lack of feathers on a broiler's head and feet, the thermal images showed a raised temperature for these parts, making the head an appropriate part for measuring body temperature. The average or Gaussian filter was first used to smooth the images, after which the Otsu automatic threshold algorithm was used to determine the gray-scale thresholds and to segment the broiler's head and feet, followed by segmenting of the overlapping broiler images via the watershed method. Area filtering was then used to identify the broiler head blocks among the segmented blocks. Finally, the labeling methodology was used to calculate the number of broilers in each image. Analysis results show that the proposed image processing procedures can successfully identify the broiler head and analyze the temperatures of the broiler flock by capturing thermal images from a height of 160 cm and a depression angle of 30°, while achieving an identification accuracy of up to 91.3%.

1. Introduction

With the development of automated livestock husbandry, the monitoring of breeding environments has become an important production management task. In broiler production management, environmental quality is a crucial factor affecting the health and productivity of broilers, and environmental temperature has a particularly important impact on broiler growth with excessively high temperatures contributing to a rising death rate and declining birth rate. New automated broiler feeding techniques for intensive production have considerably increased breeding density, with a concomitant increase in heat generated per unit of space. Without an appropriate environmental control mechanism, the broiler house will be prone to heat stress. Harsh environmental conditions may affect the physiological response of broilers and hens' egg production (Ruzal et al., 2011; Soleimani et al., 2011). Although environmental temperature is often used as the major indicator for heat stress of the broilers (Bucklin et al., 1993; Buffington et al., 1981; Oliveira and Esmay, 1982), ambient temperature does not necessarily represent the broiler's temperature perception. Rather, the broiler's body temperature is its indicator response to the environment (May et al., 1987). The deep body temperature of a normal broiler is about 41–42 °C given an ambient temperature of 25 °C and relative humidity of 50% (Lacey et al., 2000). Generally, broiler body temperature is measured directly by rectal thermometer. Not only is this method impractical for large numbers of broilers, but this kind of manual intervention can result in raising body temperature. A non-contact measurement method would therefore be preferable for obtaining accurate body temperature without disturbing the broiler flock. There is a strong positive correlation between body core temperature and facial surface temperature for broiler chickens at all ages from 8 to 36 days during exposure to acute heat stress (Giloh et al., 2012), an infrared thermal camera could be used to determine the body temperature of broilers via accurate measurement of the skin temperature, without disturbing the broiler flock. Therefore, this study chooses to measure the temperature of the naked area of the broiler's head as a proxy for the broiler's body temperature to eliminate the

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insulation effect of feathers.

For complete or large-scale measurement of the temperature of a broiler flock in a broiler house, image analysis technology could be used to analyze the body temperature of each broiler, allowing for the rapid and automatic body temperature measurement of all broilers in the flock. This study aims to develop a temperature measurement system which rapidly identifies the broiler's position in the thermal image and then determines the body temperature of most broilers in the broiler house.

2. Materials and method

2.1. Temperature values of the broiler flock in the thermal images

The thermal camera (ThermaCAM SC2000, FLIR Systems) with FOV of 24° × 18° receives the broiler's head radiation energy and the reflected radiation energy of the surrounding objects. However, converting radiation energy into temperature requires accurate emissivity of the broiler head. This is achieved by fixing a single broiler in an environment without high temperature objects. The thermal camera was then aimed at the broiler head to measure its radiation energy, after which a press-type thermocouple (Model T-600, RiXEN Tech. Co., Ltd.) was used to directly measure the broiler's head temperature. Finally, emissivity of the object was adjusted until the temperature measured by the thermal camera matching the thermocouple temperature. Once the emissivity of the broiler head was obtained, the broiler head temperature could be determined in the thermal image.

2.2. The shooting parameter tests for thermal imaging of the broiler flock

The quality of the thermal images of the broiler flock taken by the thermal camera can significantly affect the analysis results. Given accurate focusing, the distance between the lens and the broilers is the most important factor. The longer the distance, the broader the image view and the greater the number of broilers captured in the image. As the spatial resolution of the thermal images is 320 × 240 pixels, increased distance between the camera and the broilers can significantly reduce the number pixels per broiler.

This study aims to capture thermal images of broiler flocks in various broiler houses as simply as possible, thus thermal images were taken at a depression angle based on the average height of an adult human. From this vantage point, images captured at a depression angle show equally sized broilers at different positions occupying different number of pixels. Thus the depression angle is the key variable in the image capture process. A small depression angle resulted in far-away broiler heads occupying an insufficiently large number of pixels to ensure an accurate count. Likewise, too large a depression angle resulted in too few broilers being captured in the image, thus increasing the time and effort required for measurement.

The thermal camera was mounted on a tripod, with the lens at a height of 160 cm above the ground to approximate eye level for an adult human. The depression angle was set at 15°, 20°, 30° and 40° to analyze the effect of the depression angle on the resulting images, with 10 images captured at each angle. Finally, the number of broilers counted from image analysis was compared with results from a picture from an ordinary camera to determine the identification accuracy obtained with the various depression angles.

2.3. Image analysis procedure

After capturing the thermal images of the broiler flock, the image processing method was used to segment and to identify the blocks of the broiler heads in the thermal images of the broiler flock. Thereafter, the number of broilers in each image was then determined, along with their individual temperatures. The temperature distribution of the broiler flock was then displayed with a human–machine interface established by Visual Basic. The image processing procedure consisted of image acquisition, image smoothing, image segmentation, area filtering analysis and counting of broilers.

2.3.1. Image acquisition

Image acquisition directly converted the images taken by the thermal camera into .mat format files, which were then downloaded into the MATLAB for image analysis as shown in Fig. 1(a).

2.3.2. Image smoothing

To reduce image noise, and to smooth the edges of the segmented target (broiler head), image smoothing was performed prior to image segmentation. The average filter and Gaussian filter are commonly used for smoothing, with the smoothing level of the images depending on the mask size with larger masks producing a higher degree of smoothing. To determine the optimal pre-processing effect, this study compared four sizes of masks, 3 × 3, 5 × 5, 7 × 7 and 9 × 9. Fig. 1(b) shows the results after the Gaussian filtering with a 7 × 7 mask.

2.3.3. Image segmentation

As broilers have the lack of feathers on their heads and feet, the temperature at these areas is higher than elsewhere on their

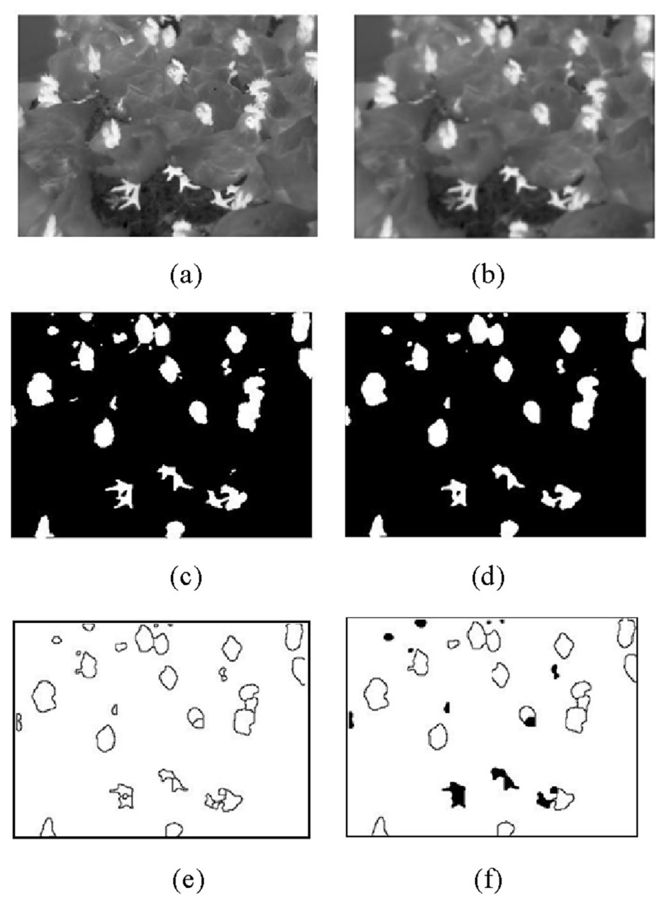

Fig. 1. Image processing results.

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