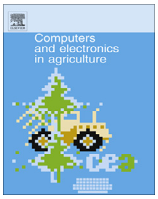
Computers and Electronics in Agriculture 141 (2017) 81–95

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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



Original papers

A framework for crack detection of fresh poultry eggs at visible radiation

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ARTICLE INFO

Article history:
Received 10 January 2017
Received in revised form 3 May 2017
Accepted 10 July 2017

Keywords:
Egg
Crack detection
Candling light
Image segmentation
Support vector machine

ABSTRACT

Visible radiation technology is increasingly being used for inspection of crack in the eggshell. However, the complexity of the eggshell together with the heterogeneity of the egg internal structures, resulted in very textured image especially when view under candling light. Hence, the inspection process is technically very challenging. In an attempt to improve the inspection performance, a refined anisotropic diffusion filter together with the double thresholding algorithm are used to morphologically segment crack pixels from the background. In this case a novel technique based on Radon transform is developed for feature extraction while the classification is established via a multiclass Support Vector Machine (SVM). Experimental results indicate that the proposed framework performs well on eggs from same or different poultry houses with sensitivity and specificity, averaging at 89.2% and 94.6% respectively. The ROC analysis produced 100% correct classification of intact or unbroken eggs. However, the performance decreased slightly when inspecting different types of cracked eggs with false positive ranging from 3 to 11% due to high degree of similarity between groups.

1. Introduction

Like other brittle materials, egg shell can be easily broken when struck by another egg or hard surface. Overall between 8 and 10% of eggs suffer shell damage due to mechanical impacts at the moment of laying or during processing and handling (Macleod et al., 2006). The first impression of consumers of egg purchased is based on their perception of shell quality. Any sign of broken shell would lower the quality of an egg, making it less saleable. A broken egg can also cause the egg contents to exude through the shell, thus increasing the risk of bacterial infection and food safety (Xiaoyan et al., 2010). Shell quality is also one of the most important factors that influence hatch ability as the reduction in eggshell quality results in the weakening of embryos. Therefore, identifying broken eggs automatically has been the long outstanding goal in poultry farming industry. Under the European Union Marketing Regulations, only egg with acceptable quality like free from dirt, stain and uncracked is allowed to be retailed for human consumption (European Commission, 2003). Similarly the Standard Research Institute of Malaysia (SIRIM) has developed specifications for egg grading. Known as the MS 680:2013, this standard groups eggshell integrity into two visible categories, (i) broken and (ii) unbroken. Even though the egg grading is still on voluntary basis, however, many large food conglomerates and distributors are performing the screening due to demand by customers and food hygiene. To-date many operations in the poultry farming in Malaysia have already been automated, however, the crack inspection continues to be manual and semi-manual effort. Generally, the inspection is performed by trained operators who look for any sign of crack on the shell by viewing an egg from different angles. Hence the process is very time consuming, tedious and subjective. Therefore, the use of automated grading system could improve the grading control process, reduce the work load on operators, and ultimately save cost and time.

Traditionally egg cracking is due to mechanical impact whose force is strong enough to cause the shell to rupture, without necessarily causing it to collapse inwards. Such an impact usually causes the formation of multiple cracks that propagate radically from the point of impact in all directions. The gross and star cracks are examples of this type of crack. Both are generally visible to naked eyes. In addition, there is another type of crack which is generated by weak mechanical force, resulting in the formation of a very minute or hairline type artifact. Referred to as the micro-crack, this type of defect is more prevalent in modern poultry processing facilities which operate at high-speed. With the width of a crack ranging from 20 to 40 µm and length averaging at 30 mm (Orlova et al., 2012), the micro-crack is more difficult to detect because this type of defect can only be visualised electronically. In spite of these difficulties and technical challenges, however,

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http://dx.doi.org/10.1016/j.compag.2017.07.006
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several attempts have been made to develop an automated online crack detection system. To-date two different models have been investigated, resulting in the varying degree of success. They are (1) the acoustic response (AR) (Wang and Jiang, 2005), and (2) the computer vision (CV) (Lawrence et al., 2008). In principal the AR system analyses the changing in impulse response and uses this information to differentiate between cracked and intact eggs. During detection a weak acoustic signal is produced by carefully impacting an egg using a small pendulum. Since the acoustic response for cracked shell is significantly smaller compared to intact shell, therefore, it is theoretically possible to perform detection by analyzing the characteristics of the measured signals in the frequency domain. For instance a vibration-based detector was developed to inspect the hairline cracks on the eggshell utilising multiple features extracted by wavelet and SVM classifiers (Deng et al., 2010). Even though this method yielded impressive results with more than 90% accuracy and less than 1% false rejection, however, it has one major drawback. The right force must be applied in order to preserve the integrity of eggshell before and after impact. If the force is too weak then the response would be very noisy, causing difficulty in analysis and increasing the false alarm rate. In contrast the eggshell would permanently be damaged if an excessive force is applied. Therefore a correct force must be calculated prior to testing. This is very time consuming procedure since this parameter depends on stiffness and thickness of the shell which usually vary from one egg to another. Additionally the AR requires calibration and finer adjustment particularly the mechanically sensitive components like pendulum, transducer and electronic detection circuits. This adds more complexity into the overall machine set-up. Meanwhile CV measurement uses candling light as a source of illumination, thereby, enabling both the exterior and interior properties of an egg be visualised. In this system, the egg is placed on top of candling light, forming the backlighting image capturing strategy. The micro-crack forms white pixels in the image since shell membranes and fibers are fairly transparent to visible light radiation. Previous study demonstrates the usefulness of this technique in detecting micro-crack with accuracy more than 90% (Lawrence et al., 2008; Yongyu et al., 2012). However these authors performed measurement by force opening the micro-crack using a small vacuum chamber so that it can be detected by CV inspection. This could irreversibly increase the size of a crack, resulting in a permanent damage to a shell if excessive pressure is applied. Generally it is preferred the inspection to be performed at atmospheric pressure such as the work by other authors (Pan et al., 2011). However, the detection rate resulted from this study is relatively low, averaging slightly over 60% especially when inspecting micro-crack samples. Furthermore, the accuracy of CV methods depends critically on the types of eggshell cuticles whose intensity varies from one egg to another. Chemically, the cuticles comprise of 85–90% proteins, polysaccharides 4%, lipids 3% and porphyrin pigments, and these compositions depends on many factors like the freshness, hen age and genetics (Rodríguez-Navarro et al., 2013). These materials are responsible for the complicated heterogeneous textures of the eggshell especially when view under the candling light. The presence of other anomalies such as dirt, scratches and grains increase the complexity of the CV images, and hence, making the process of crack detection more difficult. Solving this problem requires a very robust image processing algorithm and reliable machine learning technique. This study is aimed at developing a framework to accurately segment the crack pixels in very heterogeneous background. In so doing an improved anisotropic diffusion filter (ADF) is proposed for image enhancement while the Radon transform (RT) is utilised for edge detection. Meanwhile, the Support Vector Machine (SVM) is employed in machine learning and classification. The details are described in the following sections.

2. Materials and methods

2.1. Micro-crack system

The hardware used in this work comprises of two *RGB* cameras, the colour frame grabber board (CFGB), rotating table and a candling light source as illustrated in Fig. 1. The grabber board is Meteor II/Multi-channel MC/4 which has six independent analog input channels. This board can support switching between input from two *RGB* cameras alternately. It is also equipped with 32-bit PCI interface bus which is capable of transferring data at a peak transfer rate of 132 Mbytes/s. This speed is sufficiently fast for this type of application. Meanwhile both cameras are 8-bit CCD type, 644 × 484 resolution and manufactured by Hitachi Incorporated, Japan. Operating at a clock rate of 12.7 MHz, this camera is capable of capturing video signals at a real-time speed of 30 fps. As illustrated in Fig. 1, the cameras are positioned at a height 50 cm and mounted diagonally opposite each other. The distance is fixed rigidly at 11.5 cm from either side of an egg in order to produce a focused image and reduce artifact due to blurring. In this set-up the first camera is used to capture the first side of an egg while the opposite side is visualised through a second camera. The candling light, in this case, is the 38 W halogen lamp manufactured by The Schlueter Company, Wisconsin, USA. Placed on a PC-controlled rotating table, the candling light is programmed to rotate at discrete angles of 0, 90, 180 and 270 degrees, enabling all four sides of an egg be imaged. In this way more than 95% of the shell surface can be inspected except small areas at the base and top of the egg. The set-up in Fig. 1 is operated in a dark room to prevent interference from background lighting system.

2.2. Egg samples

Altogether 600 fresh eggs are used to test the methods and procedures developed for crack inspection. All samples are directly acquired from different poultry farms within one day of laying. Only two different types of cracks are considered in this study following the MS 680:2013 standard. The first type belongs to visible crack category like the gross and star cracks. Herein they are referred to as the major or macro-crack. The second type belongs to category which is almost completely invisible to naked eyes. This defect is referred to as the micro-crack. Example of images comparing intact and broken eggs is shown in Fig. 2. Images are also captured with background lighting, serving a comparison to candling light illumination. Clearly the macro-crack can be visualised with and without candling light as evident from Fig. 2(a)(iii) and (b)(iii). In contrast the micro-crack is completely hidden when view under background illumination as illustrated in Fig. 2

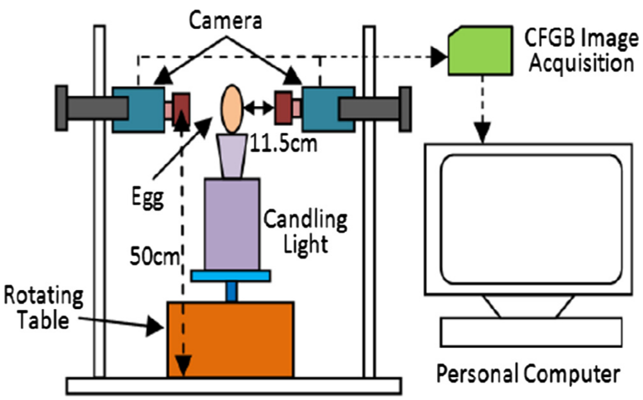

Fig. 1. Hardware set-up of eggshell inspection based on candling light illumination.