Grading and Quality Inspection of Defected Eggs Using Machine Vision

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Abstract

This paper presents algorithms based on image processing for detecting internal blood spots and eggshell dirt by processing acquired images from eggs under different illuminations. The algorithm can also detect the severity of dirt on eggshell. In order to carry out image processing and extract useful features of captured images of eggs by machine vision we developed an algorithm in HSI color space. The hue histogram was used for blood spots detection, and maximum values of two ends of histogram were selected as criterions of defect detection. Eggshell dirt was detected using connected areas detection technique. The results of experiments showed that accuracy of differentiation of blood spots algorithm was 90.66% of defected eggs and 91.33% of intact eggs and total average of this algorithm was 91%. Accuracy of differentiation of dirt detect algorithm was 86% of clean eggs, 83% of low dirt eggs and 88% of high dirt eggs. Then total average of this algorithm was 85.66%.

Keywords: *Egg, Grading, Quality inspection, Machine vision, Defect detection.*

1. Introduction

Various techniques including optical, mechanical, electrical and acoustical have also been used for classification and/or sorting of defected eggs [9]. Garcia-Alegre et al. [3] (1998) used machine vision system to detect defects in eggs. This research was done on brown eggs. Patel et al. [7] (1998) carried out a study by training neural networks with color histogram obtained from color images. Usui et al. [10] (2003) used near infrared (NIR) spectroscopy to detect blood spots in eggs. Mertens et al. [5] (2005) developed a computer vision algorithm for dirt detect on brown eggshells and determined size of defected eggs too. Aghkhani et al. [1] (2005) processed black and white images of eggs for defect detection. De Ketelaere et al. [2] (2005) detected blood spots using combined reflection-transmission spectroscopy method. Pourreza et al. [8] (2008) applied an adaptive threshold based on discontinuities determination the filtered images for detecting eggshell defects such as dirt and cracks.

The objective of this study was to develop algorithms based on image processing method that detects internal blood spots and eggshell dirt by processing acquired images from eggs under different illuminations. The latter algorithm also detects the severity of dirt on eggshell.

2. Materials and methods

In this research, white eggs in different sizes from small to large were used. For blood spots detection, 150 intact and 100 defected eggs and for dirt detection, 200 intact and 150 dirty eggs were selected from a commercial packing station. The bloody eggs had been inspected by trained operator and were broken after imaging for making sure from being internal blood spots and the results were recorded. Determination of correct performance of operators was prepared by this method. In addition, the dirty eggs were collected from samples that having several severity of eggshell dirt.

Figure 1 shows a view of used hardware system. The eggs were placed in the illumination box and the camera that had been placed above it, took images from them. The wooden cubic illumination box with dimensions of 40×40×40 cm prepares possibility of light adjustment and light noises removing. A SAMSUNG™ CCD camera, SDN-550 model was used for imaging and the distance between lens and egg was approximately 200mm. The camera has 768 and 576 pixels in horizontal and vertical directions respectively and its resolution is 530 TV lines.

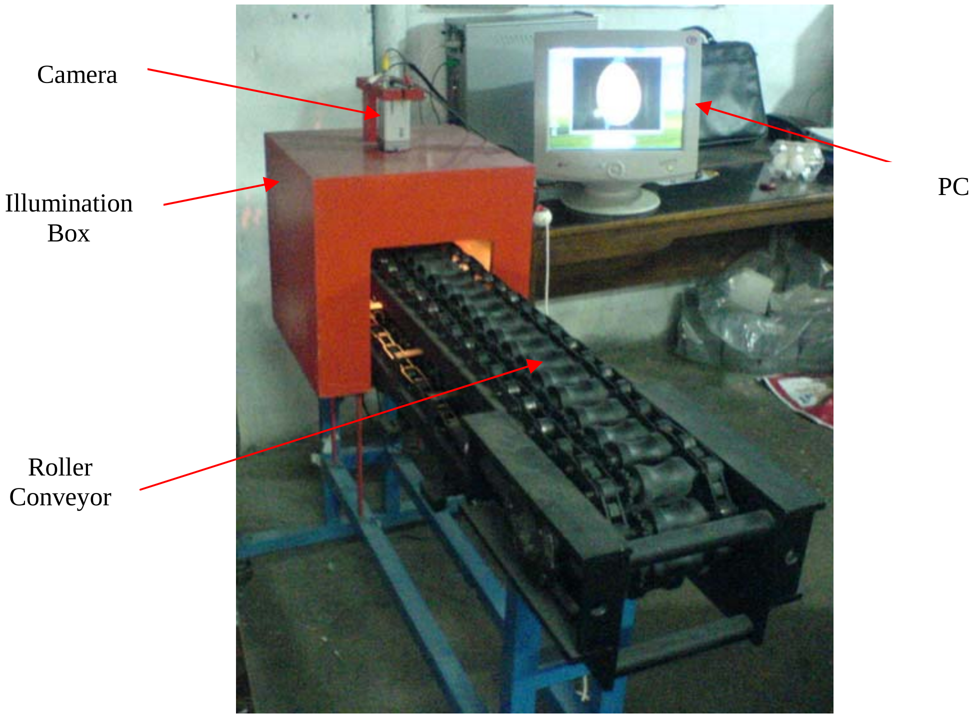


Figure 1. The hardware system

The camera was connected to a personal computer (PC) through a WINFAST™ frame grabber. This device digitizes the images and saves them on hard drive. The PC was used for observation and analysis of images. The illumination system is lighting from down for blood spots detection. In this case, a 50W halogen lamp was installed below of rollers of conveyor that was carrying the eggs. In the continue of research we realized the system of illumination from down is not suitable for dirt detection and for this section the illumination from up was selected. Accordingly, several fluorescent tubular lamps with yellow and white light were attached on the inside of illumination box, except the bottom and the top, eight lamps in total.

MATLAB 7.6 software was used for developing image processing algorithms. After acquiring the images and analyzing them for defects detection, it is necessary to carry out some operations on images. Whereas the distinction between defected and intact eggs images (for both defects) is visible for human eyes, a color space should use that to be closer to human operator performance. Therefore, since HSI color space has more capability was used. Since MATLAB does not support this color space, then HSV color space (very similar to HSI) was used instead. The hue component (H) in this color space that is variable from zero to one seems suitable for operation. In this range, zero and one mean red and black colors, respectively.

The steps of images preprocessing are:

1) At first, it is necessary for equalizing of process condition, dimensions of image to be equal.

2) In next step, RGB color image is converted to gray scale and HSV images, in two separate stages. Use of gray scale is for removing unvalued data of images, increasing speed and efficiency of sorting algorithms. Meanwhile in this step hue component range (H) converted into zero to 360.

The equations of converting colors from RGB to HSI are [4]:

$$H = \begin{cases} \theta & B \le G \\ 360 - \theta & B > G \end{cases} \tag{1}$$

$$S = 1 - \frac{3}{(R+G+B)}\left[\min(R,G,B)\right] \tag{2}$$

$$I = \frac{1}{3}(R+G+B) \tag{3}$$

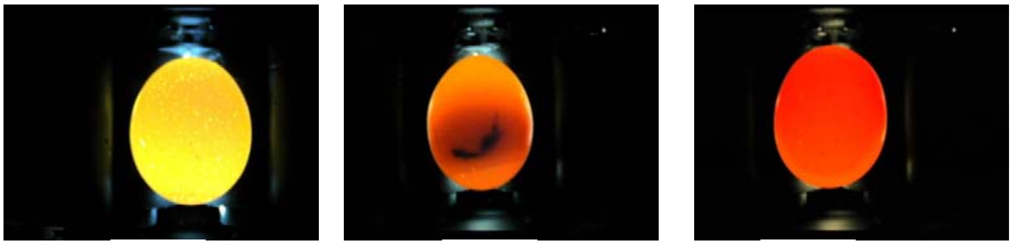
where $\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}\left[(R-G)+(R-B)\right]}{\left[(R-G)^2+(R-B)(G-B)\right]^{1/2}} \right\}$

3) In the illumination section, some undesirable noises are produced in final images. Therefore, in this step, a threshold on gray scale image can control the amount of image brightness more. Indeed, V and S components in HSV are varying and other bright subjects especially light source and effects of light reflection from outside are remove by this method.

2.1. Blood Spots

Since the making-decision about being blood spots in eggs is crisp and even some blood in egg is sufficient for removing egg from production cycle [6], thus defect severity measurement is not necessary in this section. Also because of a good color distinction between bloody egg and other parts of image, it is not necessary separating the egg from background. Therefore, the development of algorithm becomes easier and the time of image processing reduces. Although here we can do segmentation operation by proposed method in next section and separate egg from background.

The blood in egg changes colors of materials inside the egg. Depending on the amount of blood, these changes may be large or small. With observation of these eggs by halogen lamp, yellow light can display blood spots. Figure 2 shows two samples of defected case and one intact egg.



(a) (b) (c)

Figure 2. (a) A intact sample, (b) and (c) defected samples

As seen in the figure, defected eggs can be recognized in two different situations: In some of them, the blood has spread in egg albumin and covered whole material of inside the egg and in some others, the blood spots has formed on yolk. Defected eggs have more red color than intact eggs. However intact eggs are more yellow. After preprocessing because of the egg is the most colored of image, then implementation of preprocessing almost separates the egg from background and next section of processing becomes easier and faster. Therefore, after this section colored space (H) of image is indicator of egg color properties. The steps of image processing for detection of this defect are:

1) Hue color was selected as workspace and histogram of image was obtained in the range of zero to 360. With plotting histograms of a large number of intact and defected eggs we can achieve to good results for defect detection. After several surveys, we found out in bloody eggs that blood has spread inside egg, hue component has more frequency between 0 to 20. However, in intact eggs hue has more frequency between 40 to 60. This is also in accordance with the fact that bloody eggs are redder and intact eggs are more yellow. In addition, in the eggs having concentrated blood spot, the histogram has some hue in range of 200 to 359 because of the spot seems dark and close to black color. Figure 3 shows image histograms of defected and intact eggs shown in Fig. 2.

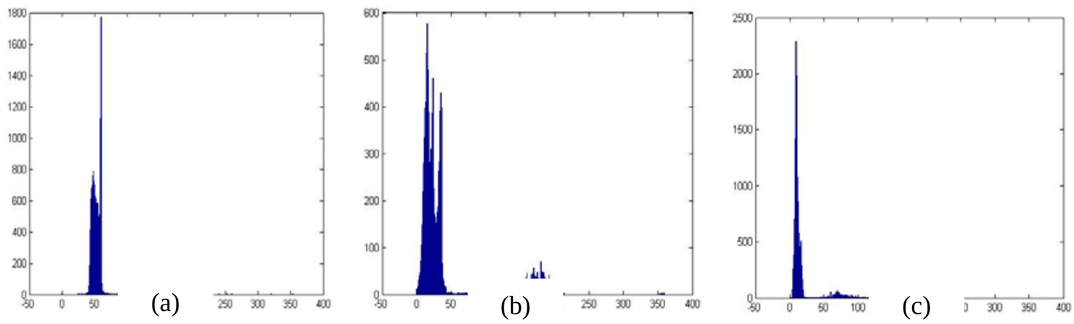


Figure 3. The hue histograms of Fig. 2 (a), (b) and (c) eggs, respectively

2) In this step, histograms of images were analyzed. Maximum values of histogram from both side of it (min-max) were achieved (minimum value from zero side and maximum value

from the end of histogram). The ratio of these two values was selected as main criterion of decision-making. The results showed by achieving to proper values of this ratio can distinguish between intact and defected eggs.

Since in this method we used frequency of colors and maximum value ratio then the size of eggs has no effect on analysis, i.e., the sorting algorithm is invariant to size, direction and rotation of egg.

2.2. Dirt

Whereas the severity of eggshell dirt is different in eggs, so for this case the severity detection of defects is important. Therefore, it is necessary to separate eggshells from image background. Since image acquiring has done in normal condition and the eggs have placed on roller conveyor, parts of conveyor were seen in images. The segmentation operation became more difficult because of this problem. After implementation of preprocessing step, the segmentation can be done easier. First, the gray scale image was selected as workspace. Then canny edge detection method (Gonzalez and Woods, [4] 2002) was used as one of edge detection techniques and finally index of this function was considered equal to 0.9. Figure 4 shows result of segmentation.

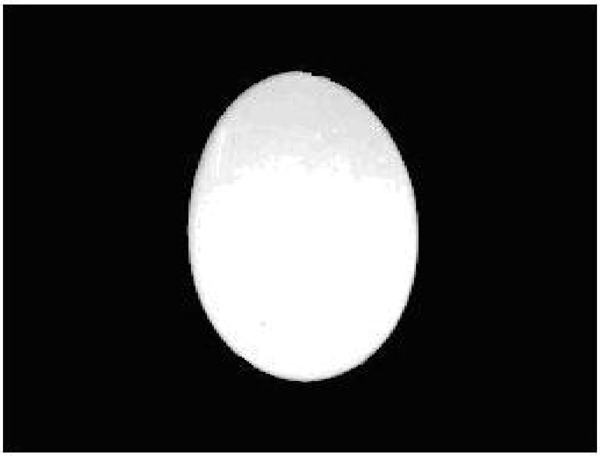


Figure 4. Segmentation of egg from background

Now in this step, *bwLabel* function in MATLAB was used as one of connected components detection methods. By this function, a distinction was defined between several areas such as background, eggshell and stains on eggshell. This possibility was existed that light noises and tiny pores on eggshell would be detected as dirt stains. For resolving this problem very small areas that was detected by *bwLabel* was removed. This makes little errors in correct detection but contain better result in total. After this step, the pixels that were on eggshell but were not defined as eggshell area, would be the dirt stains. By counting dirty pixels, we could measure eggshell dirt severity. Figure 5 shows steps of detection.

For determining eggshell dirt, severity was used from human expert as criterion of decision-making. Forty clean and dirty eggs images and appropriate questionnaire were provided for human expert for determining defect severity and categorizing images in one of sets of clean, low dirt and high dirt. Then every image sets were used as initial data for learning of sorting algorithm. The developed algorithm recorded and saved maximum and minimum values of dirt in every set as criteria of decision-making.

(a) (b) (c)

Figure 5. Successive steps (from (a) to (c)) in dirt detection on a sample with high dirt on eggshell

3. Results and Discussion

In order to evaluate developed algorithms, their performance on intact and defected eggs was tested. Tables 1 and 2 show the obtained results from tests on both of defects and intact and defected eggs and comparison of proposed algorithm and human expert. If the algorithm detects defected egg as intact egg then incorrect product exits from system, the algorithm has not done its main duty. In addition, if the algorithm detects intact egg as defected egg, defected egg does not exit but it is not economic and has financial loss for producer. These errors are called under-pull and over-pull, respectively.

Table 1. The obtained results from tests

Defect Type	Egg grade	Number	Correct Detection (%)	Total Detection (%)
Blood Spots	Intact	150	90.66	91
	Defected	150	91.33	
Eggshell Dirt	Low dirt on shell	100	83	85.66
	High dirt on shell	100	88	
	Clean	100	86	

Blood Spots. The results shows in detection of defected eggs, the algorithm has detected 90.66% correctly and 9.34% of defected samples have been detected as intact eggs (Table 1). Whereas the samples had obtained from a commercial packing station after eye inspection by operators, it was necessary that be verified being blood spots in eggs by breaking them after tests. The results determined that correct performance of operators was 87.23%. This test implemented on intact eggs and algorithm had correct performance in 91.33% of cases. The average of these two values that is called total correct detection of algorithm is 91%.

Dirt. The performance of algorithm to detect dirt is given in Table 2. The results shows detection were correct on clean eggs in 86% of them, on eggs with low dirt in 83% of them and on eggs with high dirt in 88% of them. The average of these values is 85.66% of samples totally.

Table 2. Comparison of image processing algorithm and human expert in grading of eggs

Egg Grade		Image Processing Detection				
		Clean	**Low Dirt**	**High Dirt**	**Number**	**% Correct Detection**
Human Expert	Clean	**86**	9	5	100	86
	Low Dirt	6	**83**	11	100	83
	High Dirt	1	11	**88**	100	88
Total observed		93	103	104	(257/300)*	85.66
(%)		92.5	80.6	84.6		

* Number of eggs correctly classified by proposed image processing algorithm

4. Conclusions

In this study, image processing techniques were used to detect eggs defects. According to defect detection performance of trained operator, the accuracy of algorithm is acceptable. After evaluating the samples that the algorithm has done incorrect detection on them, was determined in some cases, detection has been difficulty also by operators. This problem has happened more for intact eggs with more yellow yolks. Because of yolk seems a little reddish after directing the yellow light through it. Also in dirt detection, the lowest correct detection was on the eggs with low dirt on their eggshells. The clean eggs and eggs with high dirt were detected easier that it is more probable in eye inspection by human workers.

Acknowledgments

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References

[1] Agh khani, M. H. and A. Pourreza. **2005**. Egg Sorting by Machine Vision Method. Research Note. Journal of Agricultural Engineering Research. Vol. 8, No. 3.

[2] De Ketelaere, B., K. Mertens, B. Kemps, F. Bamelis, E. Decuypere and J. De Baerdemaker. **2005**. Improved Blood Detection in Consumption Eggs Using Combined Reflection- Transmission Spectroscopy. XIth European Symposium on the Quality of Eggs and Egg Products. Doorwerth, The Netherlands, 23-26 May.

[3] Garcia-Alegre, M. C., A. Ribeiro, D. Guinea and G. Cristobal. **1998**. Eggshell Defects Detection Based on Color Processing. International Workshop on Robotics and Automated Machinery for Bio-Productions. Spain. Pages 51-66.

[4] Gonzalez, R.C. and R. E. Woods. **2002**. Digital Image Processing. Second Edition. Prentice Hall Inc.

[5] Mertens, K., B. De Ketelaere, B. Kamers, F. R. Bamelis, B. J. Kemps, E. M. Verhoelst, J. G. De Baerdemaeker and E. M. Decuypere. **2005**. Dirt Detection on Brown Eggs by Means of Color Copmuter Vision. Poultry Science Association Inc. (2005) 84: 1653-1659.
[6] North, M. O. and D. D. Bell. **1990**. Commercial Chicken Production Manual. Fourth Edition. Van Nostrand Reinhold: New York.
[7] Patel, V. C., R. W. Mc Clendon and J. W. Goodrum. **1998**. Color Computer Vision and Artificial Neural Networks for the Detection of Defects in Poultry Eggs. Artificial Intelligence Review (1998) 12:163-176. Khwer Academic Publishers. Printed in Netherlands.
[8] Pourreza, H. R., R. S. Pourreza, S. Fazeli and B. Taghizadeh. **2008**. Automatic Detection of Eggshell Defects Based on Machine Vision. Journal of Animal and Veterinary Advances 7(10): 1200-1203.
[9] United States Department of Agriculture. **1990**. Egg-Grading Manual. Agriculture Handbook No.75. Agriculture Marketing Service, USDA.
[10] Usui, Y., K. Nakano and Y. Motonaga. **2003**. A Study on the Development of Non-Destructive Detection System for Abnormal Eggs. EFITA Conference. Debrecen. Hungary.