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Automatic Detection of Eggshell Defects Based on Machine Vision

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Abstract: Grading defected eggs is one of the important needs of poultry industry, because of sanitary and also economic reasons. Separating cracked and dirty eggs in primary steps of packing is an inevitable necessity to protect other eggs and mechanical parts from contamination. This study presents an automatic method based on colored image processing for recognition of eggshell defects. This method is based on recognition of discontinuities in image caused by eggshell defects. This algorithm uses a high pass filter to determine discontinuities. Finally, the deficiency of an egg is considered after applying an adaptive threshold to the filtered picture. The result of this method is more reliable than the methods given before.

Key words: Machine vision, image processing, histogram, high pass filter, sorting, poultry industry, egg

INTRODUCTION

An important point in progressing food and poultry industry is use of mechanization in general and machine vision in production in particular. More desirable products, reducing the costs and better marketing are the results of using industrial poultry. High importance of egg as an alimentary source has caused special attention to poultry industry from produce to delivery to consumers. This process include gathering, washing, grading and packing. Dirt of the eggshell consists of some harmful bacteria. If they penetrate in to the shell, the egg will be poisoned and the health of the consumers will be threatened. On the other hand the presence of dirt will pollute the mechanical parts which will contaminant the other eggs. Classification of eggs in primary steps may solve these problems. Having a well appearing product is very important in marketing. In most factories separating defected eggs from no defected ones is done by workers, while problem of human like low speed, weariness and hard work not only affect the health of the workmen but also will reduce the rate and quality. So, any automation in grading will increase the efficiency.

Up to now different researches have been done for automation of identifying defected eggs by image processing technology and machine vision. Maria and teammates have used classical transforms on colored images (García-Alegrea *et al*., 2000). Ribeiro *et al*. (2000) have used thresholding and finding the threshold using high pass filters has been suggested by García-Alegrea *et al*. (1997). Patel and cooperators have used N.N (Patel *et al*., 1994, 1996, 1998) with histogram vector as input. Among these methods just N.N. can identify the type of the defects. Generally, given methods can be divided into 2 groups:

- Use of color images for detection of eggshell defects.
- Using the discontinuities of the grayscale image.

Working on color images has some problems which can disorder the system work. Some of the problems are as follow:

- Heterogeneous illumination.
- Eggs with different colors.
- Variety of eggshell defects.

Although, high speed of Neural Network based algorithms (Patel *et al*., 1994, 1996, 1998) with histogram vector as input, sever dependence on the learning set is the main problem of them that might cause a great error.

Use of discontinuities of the image is less sensitive to illumination and noise but it has its own problems:

- It is dependent to the direction of egg in the image.
- It is more time consuming than former methods.

Because of the mentioned reasons this article presents an algorithm based on recognition of discontinuities in image caused by eggshell defects.

PROPOSED ALGORITHM

To suggest a new algorithm first we studied and exerted introduced algorithms for determination of

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defected eggs. Because of high precision and independence of illumination conditions, high pass filter based method was selected as a base for our algorithm and we tried to improve its performance.

Because of the mentioned reasons, in the present article first the Region of Interest (ROI) which is the inside area of eggs border is found, then inside area of the peripheral rectangle on ROI is filtered by Gradient North-West filter and by applying an adaptive threshold to the filtered image a binary image is produced. Then the egg border which is found before is fitted with an ellipse, to omit border effects. Finally, active pixels in the binary image are counted to denote if it is defected. In continue any of these steps is expounded.

Minimizing the error of identifying border points as defects is obtained by separating the egg from background. In addition, minimum dependence on illumination conditions and other available outside noises is achieved by utilizing adaptive threshold.

Discontinuities recognition: Using high pass filters, is one of discontinuity based methods, which identify the parts with severe discontinuities. Two kinds of high pass filters are suggested to light discontinuities containing edges and dirt.

The first one is the famous Laplacian filter with coefficients like below:

$$\text{Laplacian filter: } \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

Sensitivity to noise is the main disadvantage of this filter (Gonzalez and Woodl, 2002). To solve this problem, Gradient North-West filter is suggested. In this filter averaging brightness of adjacent pixels in each column before subtraction causes reduction of noise.

$$\text{Gradient North-West: } \begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

The Gradient North-West filter lights discontinuities only in one direction.

We use Gradient North-West filter in this method.

Egg border cancellation: To avoid the effect of border which is appeared as a discontinuity after applying filter, it is necessary to omit the egg border. For this purpose, whereas the egg has an elliptical form, we can estimate the egg border with an ellipse. To do this we use the Least Square Estimator. Using LSE, the model should be linear with respect to the parameters (namely $A\theta = y$).

According to, the formula of ellipse,

$$\frac{1}{a^2}(x - x_0)^2 + \frac{1}{b^2}(y - y_0)^2 = 1 \quad a > b \tag{1}$$

In which, a and b are half of the largest and smallest diameters, respectively and (x_0, y_0) is the coordinates of center of the ellipse; we have $1/b^2$and $1/a^2$ as parameters and

$$A = \left[(x_n - x_0)^2 \quad (y_n - y_0)^2 \right]_{n\times 2},$$

$$\theta^T = \left[\frac{1}{a^2} \quad \frac{1}{b^2} \right] \text{ and } Y = [1]_{n\times 2}$$

where, n specifies the number of border points.

As we know, the given formula is for a horizontal ellipse. But in some images the egg may not be placed horizontally, so it is necessary to rotate the image of the egg before using LSE algorithm. To do this, first we should find Region of Interest (ROI) which contains area inside the egg border. By the way as explained below to find the border, we select a threshold and scan each row of the image matrix, if the intensity of a pixel is higher than the threshold, the next pixel will be checked. If the next 5 pixels have higher intensities than the threshold, the 5th pixel is selected as a border point. The center of the peripheral rectangle of ROI is recognized as the center of the egg. We use ROI matrix to put a peripheral rectangle on the ROI area. Each row of this matrix contains coordinates of the beginning and the end of the egg border in the corresponding row of image. By using this matrix the maximum and minimum border points on horizontal and vertical axes are recognized correctly. The lines which pass through these points which are parallel to the axes show the sides of the peripheral rectangle. To avoid unnecessary calculations we do the processes only for the inside region of the peripheral rectangle. Distance of each border point from the center of this rectangle is computed and the largest distance specifies the half of the large diameter of ellipse. To make a horizontal figure of the egg each point of the egg border will rotate with a rotating matrix.

$$\begin{bmatrix} \text{Cos}(\varphi) & -\text{Sin}(\varphi) \\ \text{Sin}(\varphi) & \text{Cos}(\varphi) \end{bmatrix} \tag{2}$$

φ : Determines the angle between horizontal axis and large diameter of the ellipse.

After all, LSE algorithm will use border points of horizontal egg as input vector. Because of discontinuities

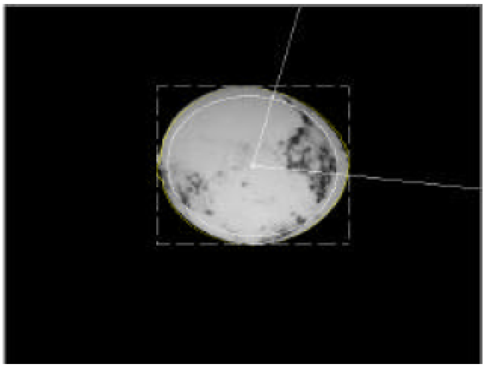


Fig. 1: Fitting an ellipse on egg border

effects, a large amount of noise exists on the edge of the egg. Therefore, the ellipse is made smaller to omit the effect of the border noise. This is done by reducing the diameters with formula shown below:

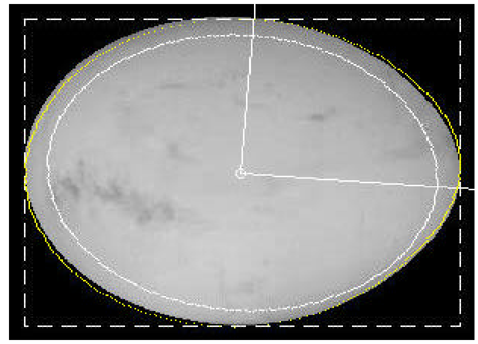
$$a = a - 0.1a$$
$$b = b - 0.1b \quad (3)$$

Remained area after omitting the border is called MASK. In this way by eliminating border effect from the image, the parameters cause mistakes, are minimized. The result of applying this method is shown in Fig. 1.

Determining the optimum threshold: To determine the threshold, inside area of the peripheral is filtered by high pass Gradient North-West filter, which was described in the study and by using the methods described in the study, the egg border is omitted. Because of the high pass nature of filter the filtered matrix has positive and negative values for discontinuous points and zero for points with monotonous color intensity. Intensity of points with negative values will be mapped to zero and values higher than 255 will be mapped to 255. Thus, there will be a histogram with two basic modes for discontinuous areas and with one mode for smooth areas. To find threshold value, the histogram is classified into 2 main classes. Initially the color intensities of zero and 180 are considered as centers of 2 classes; where any point on histogram with non-zero value belongs to its nearest class. Each point distance to each class is defined as the distance between the point and the center of the class. Then the weighted average of each class is calculated and is considered as the new center of the class. With repeating this algorithm for several times, 2 modes of histogram will be divided into two classes. The distance between each component of the first and second class is calculated and the minimum distance will be found. Suppose that point a belongs to first and point b to second class, make this minimum distance. Then the optimum threshold is calculated by:

$$T = \frac{a + b}{2} \quad (4)$$

This threshold is used to obtain the final binary image. Note that all mentioned processes are done in blue plane on colored image (RGB). Finally, in binary image, active points placed in mask area are counted if they are more than 0.05% of total points, the egg will be recognize as a defected one. Figure 2 shows the result of any rungs of the algorithm.



(a)

(b)

(c)

Fig. 2: (a) Fitting an ellipse on egg border, (b) using HPF, (c) binary image

Table 1: Comparison of different algorithm for detection of eggshell defects

Algorithm	Process time (sec)	Correct classification (%)
Adaptive threshold (Proposed algorithm)	0.87	99.00
Color based	0.09	65.00
Gradient north filter	0.15	85.83
Gradient north west filter	0.14	85.00
Laplacian filter	0.15	63.33
Neural network	0.04	67.50
Histogram variance method	0.07	82.50

EXPERIMENTAL RESULTS

To test the algorithm we used a database of 120, 640 by 480 images contain 54 images of non-defected and 66 images of damaged and dirty eggs. The result was 99% correct identifying defected eggs from non-defected ones. The algorithm was implemented by VB6 on a Pentium 3 (667 MHz) PC. Running the program on this computer took about 0.87 sec to determine each picture. The Table 1 prepare comparison between suggested algorithm and others.

CONCLUSION

To suggest a new algorithm first we studied and exerted introduced algorithms for determination of defected eggs. Because of high precision and independence of illumination conditions, high pass filter based method was selected as a base for our algorithm and we tried to improve its work.

Thus this method is based on discontinuities in image caused by eggshell defects. This algorithm uses a high pass filter to determine discontinuities. Finally, the deficiency of an egg is considered after applying an adaptive threshold to the filtered image and removing border area. The result of this method is more reliable than the methods given before.

The result was 99% correct identifying Grade A eggs from non defected ones.

But the process is taking too much time which is caused by using trigonometric functions (sin and cos), while rotating the egg. To overcome this problem a lookup table can be used for different values of sin and cos functions.

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