Submillimeter Crack Detection Technology of Eggs Based on Improved Light Source

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Abstract. The purpose of this paper is to provide an effective method for detecting submillimeter crack in eggs. The central idea is to enhance the crack information, because the submillimeter crack information is easy to be lost. Different from the pressure method used in previous literatures, this paper improves the light source for image acquisition. The laser light source is placed on the back of the egg, and the crack information is enhanced by the feature of high laser brightness. But the resulting problem is that stomata and eggshell edges are also noisier. To solve this problem, this paper comprehensively utilizes the characteristics of fixed threshold and adaptive threshold methods. The feature of fixed threshold is that it can select global threshold to eliminate the edge noise of eggshell with small pixels, but the stomatal noise is larger. The characteristic of adaptive threshold is that it can reduce the stomatal noise but keep the edge noise. According to the above analysis, this paper applies the two methods to obtain two result images at the same time, and performs and operates on the result image to filter the noise of egg stoma and eggshell edge, and determines whether there are cracks based on the standard of area.

In the experiment, 100 eggs were tested, and the recognition of tested, cracked and comprehensive eggs reached 90.0%, 92.0% and 91.0% respectively. The innovation of this paper is to enhance the crack information in essence by improving the light source, instead of improving the recognition degree only by improving the algorithm. The comprehensive use of fixed threshold and adaptive threshold is also one of the innovations of this paper. Previous journals only improved or compared one threshold selection method, but did not make comprehensive use of their advantages.

1. Introduction

During egg hatching, the egg should be placed in an environment of 37.8℃ and 40% ~ 70% relative humidity. However, small cracks on the egg shell will make the egg go bad [1]. Therefore, fine grain detection is of great significance for enterprises to save costs. At present, crack detection mainly consists of two methods: percussion vibration and machine vision [2]. Percussive vibration comes through acoustic signals [3-4]. And vibration sensor [5] And the majority of the test. In terms of machine vision, Yongyu Li et al. applied a vacuum pressure of 18kPa to force the crack to open in 2012 and amplified the crack information for detection in combination with machine vision [6]; Loredana Lunadei et al. used multi-spectral images to detect eggshell cracks in 2012 [7]; Bao Guanjun et al used negative Laplacian of Gaussian to enhance cracks in 2019 and used lag threshold to eliminate irrelevant black spots [8]; R. Ota-Grajales et al. designed a surface defect detection system in 2018. This vision system is based on laser mode structural light for scanning and imaging, and highlights geometric changes in the structure for detection [9]; Amin Nasiri et al used deep convolutional neural network (CNN) to classify broken and unwashed eggs in 2020 [10].
In the research of machine vision, in addition to proposing a new recognition method and index, most of them are improvements to the program algorithm [11-15]. And the influence of experimental equipment on the appearance of fine cracks is ignored. In Yongyu Li's paper, it is proposed that the crack information can be amplified by applying pressure. In this paper, the same central idea is adopted to improve the light source to enhance the appearance of fine lines. In the previous literature, the light sources used were halogen lamps and LED lamps, etc [13-15], with small brightness, insignificant cracks and easy light leakage, which would affect the detection. To solve this problem, this paper adopts the feature of high brightness laser light source to illuminate the back of the egg, which can not only effectively enhance crack information, but also effectively prevent light leakage. Meanwhile, two threshold methods are combined for effective detection.

2. Materials and methods

2.1. Test materials
Eggs: 100 brown shell eggs with the same shape were purchased from Jijia Shopping Mall in Shenbei New District, Shenyang. The measured mass ranged from 54.2g to 71.8g, and the equatorial diameter ranged from 39.5mm to 43.8mm. Cracks in the eggshell are caused by human knock against the eggshell. The crack positions are randomly distributed, of different sizes and shapes, and the eggshell is not damaged. Among them, there were 50 intact eggs and 50 cracked eggs [16].

303 Laser pointer: Shanyang Electronics Co., LTD; HP (HP) Shadow and Spirit ESPorts: China HP Co., LTD; Canon 70D(standalone): Canon Corporation; Portable detection device and image transmission circuit: self-made; The image analysis software is Visual Studio2019 and Open Cv4.1.0.

2.2. Test equipment and test method
In the experiment, the digital image of the egg surface is collected by the laser emitter and the camera mounted on the top and the interface is passed into the computer. Then the transparent container is driven by a small motor to flip, and the crack detection on both sides of the tested egg is realized on the premise of ensuring the safety of the eggs to be tested. The experimental device is connected with the top cover and the base by a removable telescopic support rod, which can adjust the distance between the top cover and the content box. Under normal condition, the support rod is compressed and easy to carry. During operation, the support rod is stretched to expand the collection range of the camera. The experimental device is shown in figure 1.
3. Results and analysis

3.1. Degree of fine grain appearance
When the crack precision reaches submillimeter level, the detection method of machine vision tends to lose the crack information and treat it as noise filtering. So in order to enhance the crack information, Yongyu Li [6]. And such as Luo Hui [11]. Pressure method was used to improve the appearance of fine lines. As for this problem, this paper puts forward the idea of using laser with high luminance as the light source to highlight the fine lines. Previous literature [17-19] LED and halogen light source with small brightness are used to detect the tiny crack, but the crack information is not obvious, as shown in the left figure of figure 2, which requires very high algorithm. However, under the irradiation of laser, as shown in the right figure of figure 2, the submillimeter crack information is enhanced, which can also be observed by the naked eye. In the recognition process below, the accuracy of the algorithm is reduced.

Figure 1. Schematic diagram of device for cracked egg detection.

1: The roof; 2: Shading curtain; 3: Rotating frame; 4: Storage box; 5: Telescopic support rod; 6 Base; 7. Electric frame; 8: Electric motor; 9: Shading cloth
3.2. threshold processing

The laser light source can effectively improve the appearance of fine lines, but at the same time, it introduces more noise of pores on the surface of eggshell and noise of eggshell edge. By means or Filtering, the above two types of noise were found difficult to be filtered by means or Filtering, which caused new interference to crack detection. Here, this paper takes advantage of the fixed threshold processing to effectively filter eggshell edge noise and adaptive Threshold processing to effectively filter large pores, and two result image matrices are obtained for the experimental images obtained by the detection device by two methods respectively. In the above two matrices, one eliminates the information of edge noise and the other eliminates the information of large stomatal noise. The common elements of the two matrices have an effect on the cracks and small stomatal noise. The enhanced crack information can be obtained by manipulating the two matrices, and the crack can be detected effectively.

3.2.1 Fixed threshold processing

In the fixed threshold operation, the threshold belongs to the global threshold, and the value needs to be set manually [20]. The previous threshold is usually determined by experience. Under different environments and light sources, the threshold needs to be adjusted manually. In this paper, a computer algorithm is proposed to determine the threshold value, and an egg brightness model is established. It is known that the brightness of eggshell thickness is directly proportional to the pixel value, that is, the pixel value is relatively large for positions with small eggshell thickness and large brightness, and vice versa. For the eggshell with pores and cracks, the thickness here is smaller and the brightness is larger than that of the eggshell without pores and cracks. For the eggshell surface without cracks and pores, the brightness of the eggshell at the center is greater than that at the edge because the indicator laser pointer is in the center at the single back. To sum up, pixel values: crack and pore > egg shell center surface > egg outer contour.

The following USES the above analysis to carry out a series of gray image processing to determine the fixed threshold threshold. Since the grayscale egg image is essentially a two-dimensional matrix, different (x,y) positions store different pixel values. Therefore, firstly, the maximum value of pixel Max is calculated through the minMaxIdx function of Open Cv, and then the average value of image pixel average is calculated through the mean function. Through experimental analysis, it can be deduced that if there is a crack, the pixel value at the crack is PX1, between the maximum Max and the average average, and closer to the maximum Max. Therefore, the fixed threshold of PX should be between average and Max by the dichotomy method, so the pixel value of the crack is PX1, between PX and Max. Similarly, the pixel value at the edge of the eggshell is analyzed to get PX2, between average and 0, as shown in figure 3.
Through the above analysis, the global threshold of fixed threshold is calculated as follows

$$\text{max} = \frac{\text{average} + \text{max}}{2}$$  \hspace{1cm} (1)

When the fixed threshold is processed, the threshold value is PX, and the pixel value at the edge of the eggshell is PX<sub>1</sub> less than the set threshold PX, the crack pixel value PX<sub>1</sub>. It is larger than the set threshold PX, so the edge information of the eggshell is not retained but the crack information is retained. This can not only filter the noise interference of egg edge, but also store the information of crack. In the experiment, the threshold function was used for fixed threshold operation, and the image obtained was shown in figure 4. It could be seen that the edge noise of the egg was well eliminated and the crack information was retained.

![Figure 3. Schematic diagram of pixels on the surface of an eggshell.](image)

3.2.2. Adaptive Threshold processing

Adaptive threshold is calculated pixel by pixel. The local threshold is obtained by calculating the weighted average value of b×b region around each pixel position and then subtracting the constant. The calculation method is as follows:

$$\text{PX}_k = \frac{\sum_{i=1}^{b} \sum_{j=1}^{b} A_{ij} \cdot \text{PX}(i, j)}{b^2} - C$$  \hspace{1cm} (2)

Where, \(\text{PX}_k\) is the local threshold of the k region, \(A_{ij}\) is the weighted coefficient, \(\text{PX}(i, j)\) is the pixel value of each point in the b×b region, and C is the constant.

The above formula indicates that adaptive threshold can be used to calculate the local threshold by setting the size of the local region according to the brightness distribution of different regions, so the adaptive threshold can better process the image threshold. Because the adaptive threshold processing, cracks, porosity and eggshell edges are an area of extreme value, using this operation will be brightness weak edge information highlights preserved egg, and the brightness of the stronger the larger hole information is abate, this allows the crack information is preserved, and weaken the noise of larger pores, the image is shown in figure 5 (the circle part to crack) shown below:

![Figure 4. The image of eggshell is processed with fixed threshold.](image)
3.3. Noise reduction
Because submillimeter crack information was easily lost, after the above two thresholds processing, this paper adopted Gaussian Filtering, morpheme and Find Contours to further reduce image noise and highlight the crack information, as shown in figure 6. Compared with figure 4 on the left of figure 6 and figure 5 on the right of figure 6, the crack presentation degree is improved, and the influence of the larger pores on the left of figure 6 is also weakened.

3.4. Crack extraction
Through the above experiments and comparative analysis, it is obvious that both the fixed threshold and adaptive threshold retain the crack information, and what they all share is the crack. The fixed threshold is interfered by stoma, and the fixed threshold is the interference of eggshell edge, that is, their interference factors are not the same. And since the image is stored in the form of Mat matrix in the computer, this paper chooses to select the crack by taking the common part of the two images with operation, and the result is shown in figure 7 (the circle part is the crack).
As can be seen from figure 7, in this paper, through the above operation, large pores and eggshell edge interference were mostly removed, leaving cracks and small pores (or background noise). During the experiment, the author found that the area of pores is generally between 10 and 100(pixel points), while the area of cracks is generally above 100(pixel points). Therefore, the connected domain with the largest area in figure 7 is selected through the for loop, which is referred to as the connected domain A. If the area of A is more than 100(pixels), it will be identified as A crack and depicted in the original image. (Because the filtered connected domain is the part with the largest area, it is only part of the crack but not all of it when displayed in the image), as shown in figure 8. Otherwise, this kind of egg has no crack.

3.5. Experimental results
Under the above operation steps, 100 eggs were tested for cracks. According to the experimental data of 100 eggs, the identification accuracy of intact eggs, cracked eggs and comprehensive eggs reached 90.0%, 92.0% and 91.0% respectively, as shown in table 1. 4 eggs were selected from 100 kinds of tested eggs to demonstrate the detection effect, as shown in figure 9. The upper left and upper right are the cracked eggs successfully identified, the lower left are the intact eggs successfully identified (connected
domain A area is less than 100 (pixels)), and the lower right are the intact eggs that are not successfully identified (large pores are mistaken for cracks).

![Figure 9. Schematic diagram of crack detection results.](image)

| type                  | Number of samples | correct | error | correct |
|-----------------------|-------------------|---------|-------|---------|
| In good condition     | 50                | 45      | 5     | 90.0%   |
| Submillimeter crack   | 50                | 46      | 4     | 92.0%   |

### 4. Conclusion

(1) In this paper, first of all, a portable egg machine vision detection system was built to collect the surface image of the egg under the laser light source. Then, a nondestructive detection method to improve the light source and improve the crack presentation degree is proposed. The fixed threshold and adaptive threshold are used to filter the edge noise and large stomatal noise of the eggshell, and the final detection results are obtained.

(2) Under the detection system and method, the recognition rate of nondestructive eggs and submillimeter cracked eggs reached 90.0% and 92.0%, respectively, and the comprehensive recognition rate reached 91.0%.

### References

[1] Fasenko G M 2007 Egg Storage and the Embryo *Poultry Sci* **86**(5) 1020-1024
[2] Sun L, Cai J R, Li Y Q, Yuan L M, Xu D C 2015 Research progress on nondestructive testing methods for egg shell quality of poultry eggs *China agricultural science and technology bulletin* **17**(05) 11-17
[3] Sun L, Feng S Y, Cheng C, Liu X L, Cai J R 2020 Identification of eggshell crack for hen egg and duck egg using correlation analysis based on acoustic resonance method *Journal of Food Process Engineering* **lancet** 8
[4] Wei Z B, Wang J, Tian X J 2014 Identification of Eggshell Crack using BPNN and GANN in Dynamic Frequency Analysis *International Journal of Food Engineering* **10**(2)
[5] Lin H, Xu P T, Sun L, Bi X K, Zhao J W, Cai J R 2018 The Identification of eggshell crack using multiple vibration sensors and correlative information analysis *Journal of Food Process Engineering* **9** 8
[6] Li Y Y, Sagar D, Peng Y K 2012 machine vision system for identification of micro-crack in egg shell *Journal of Food Engineering* **109** 127-134
[7] Loredana L, Luis R, Luigi B 2012 Automatic Identification of Defects on Eggshell Food Bioprocess Technol (5) 3042-3050
[8] Bao G J, Jia M M, Xun Y, Cai S B, Yang Q H 2019 Cracked egg recognition based on machine vision Computers and Electronics in Agriculture (158) 159-166
[9] Mota-Grajales R, Torres-Pena J.C, Camas-Anzueto J.L, Camas, Perez-Patricio M, Grajales R, Coutino F.R, Lopez-EstradaE N, Escobar-Gomez H 2018 Guora-Crespo Defect Detection in Eggshell using a vision system to ensure the incubation in Poultry production Measurement
[10] Amin N, Mahmoud O, Amin T 2020 An automatic sorting system for unwashed eggs using deep learning Journal of Food Engineering 283
[11] Luo H, Yan S M, Lu W, Zhang C Y, Dai D 2016 Chinese journal of agricultural machiner 47(11) 224-230 (in Chinese)
[12] Pan L Q, Tu K, Zhan G, Liu M, Zou X R 2010 Egg crack detection based on computer vision and acoustic response information fusion Chinese journal of agricultural engineering 26(11) 332-337
[13] Zhang J, Cui Y J 2020 Egg crack detection method based on improved particle swarm optimization Food and machinery 36(07) 136-139+226
[14] Wei X, He J C, Zheng S H, Ye D P 2017 (in Chinese) Nondestructive detection of egg microcracks based on image texture features Journal of fu jian agriculture and forestry university (natural science edition) 46(06) 716-720
[15] OuYang J Y, Liu M H 2012 Research on egg crack detection method based on computer vision Agricultural mechanization research 34(03) 91-93
[16] Ding Tianhua, Lu Wei, ZHANG Chao, DU Jianjian, Ding Weimin, Zhao Xianlin 2015 The crackle identification of poultry eggs based on Welch power spectrum and generalized regression neural network Food science 36(14):156-160
[17] Xin Y X, Huang Y B 2020 Design of a detection system for fouling and crack in poultry eggs based on machine vision Mechanical and Electrical Information 02: 108-110
[18] Po T C, Jeng L L 2008 Study of Impact Energy on Eggshell Crack IOP Conference Series: Materials Science and Engineering 378(1)
[19] Jetsadaporn P, Chawalit K, Somying T 2017 Crack Detection on Unwashed Eggs Using Image Processing Journal of Food Engineering 209
[20] Pan L Q, Tu K, Su Z P, Yang J L, Li H W 2007 Research on Detection of Egg Crack based on computer Vision and Neural network Chinese Journal of Agricultural Engineering 05: 154-158