Quality Inspection and Sorting in Eggs by Machine Vision

Han-Keun Cho, Professor
Department of Agricultural Machinery Engineering
Chungbuk National University

Yang Kwon, Engineer
Halla Engineering and Heavy Industries Limited

Abstract

Egg production in Korea is becoming automated with a large scale farm. Although many operations in egg production have been automated, quality inspection continues to be a manual effort. Sorting is necessary and cracks are regarded as a critical problem.

A computer vision system was built to generate images of a single, stationary egg. This system includes a CCD camera, a frame grabber board, a personal computer(IBM PC AT 486) and an incandescent back lighting system. Image processing algorithms were developed to inspect egg shell and to sort eggs.

Those values of both gray level and area of dark spots in the egg image were used as criteria to detect holes in egg and those values of both area and roundness of dark spots in the egg and those values of both area and roundness of dark spots in the egg image were used to detect cracks in egg. For a sample of 300 eggs, this system was able to correctly analyze an egg for the presence of a defect 97.5 % of the time.

The weights of eggs were found to be linear to both the projected area and the perimeter of eggs viewed from above. Those two values were used as criteria to sort eggs. Accuracy in grading was found to be 96.7% as compared with results from weight by electronic scale.

Keywords. Image analysis, Egg, Crack detection, Sorting.

Introduction

In Korea, most large scale egg producing farms have been highly automated. Although many operations such as cleaning, packing, and sorting have been automated, quality inspection continues to be a manual effort. Quality inspection includes flash candling operation which involves examination of cracks, blood spots, dirt spots, and undergrades (Elster and Goodrum, 1991). Though all of these defects downgrades the egg quality, cracks are regarded as a critical problem. The frequencies of defected egg due to cracks would be increased with the automation in egg production. The average fraction of cracked eggs in the processing plant of U.S.A. was reported to 4.0% (Roland, 1988).

Fast progress in artificial intelligence and declining costs in associated hardware have made automated inspection of fruits and vegetables by machine vision feasible. Machine vision system offers the potential to replace the manual candling of eggs by minimizing false identifications with improved consistency. There has been a proliferation of research into nondestructive inspecting of agricultural products utilizing image processing method. Machine vision technique has not been employed as much in agriculture as in other industries, due primarily to the complexity of images in agricultural products and a lack of appropriate image processing technology.

The machine vision systems have been developed for quality inspection and automatic harvesting of fruit and vegetable (Elster and Goodrum, 1991; Miller, 1995). At the present time image processing method appears to be the most promising technology as possible alternative to egg candling (ARC Working party, 1982). The weight measurement which is commonly adopted in most farm for egg sorting appears to be replaced with image processing. Thus both the quality inspection of egg shell and egg sorting would be feasible by machine vision.

An automatic crack detection algorithm using edge detection and contour finding method in a simulated robotics candling system is developed by Bourely et al.(1985); the results of their study suggested the possibility of complete automatic candling. Machine vision system with back lighting was developed to identify a crack in a stationary egg by Elster and Goodrum(1991). Their system showed that cracks in commercial eggs were detected with a success rate of 96%. A sequence of three images per egg was investigated for cracks by Goodrum and Elster(1992). An angular rotating system was designed to inspect entire egg surfaces for cracks. Their system was able to correctly analyze an egg for the presence of a crack 94% of time. The global image analysis procedure using two-dimensional FFT was applied to egg shell inspection by Han and Feng(1994). Their inspection models showed the success rate of 88% in commercial eggs. Cho and Kwon (1996) constructed the machine vision system and an algorithm to detect the cracks in eggs, and they showed their system could detect cracks with success rate of 95%.

To investigate the feasibility of machine vision for egg inspection and sorting, the following objectives were selected:

1. Investigate the feasibility of machine vision system to sort eggs by size.
2. Develop an algorithm to recognize the cracks in egg shell and to sort eggs by machine vision system.
3. Evaluate a machine vision system and an algorithm based on their ability to detect cracks and to sort eggs by size.

Materials and Methods

Experimental Vision System

The experimental vision system used in this study is explained in detail at the report of previous study (Cho and Kwon, 1996). Table 1 shows the specification of equipment used and Figure 1 shows the schematic diagram of experimental system used in this study.

Egg Samples

INSPECTION OF EGG SHELL

Three sets of eggs were inspected by the experimental system. First set was obtained from a commercial egg producer equipped with highly automated facilities. Second set was obtained from a commercial egg producer equipped with conventional facilities. Third set was obtained from a typical grocery store. Number of each set of samples was 70 respectively, so 210 eggs were used in evaluation of system. Eggs were selected to include a wide variety of defects and ranging from eggs with leaking cracks to non-defective eggs. In the test of algorithm effect on the success rate, 50% were cracked and 50% were crack-free.

EGG SORTING

One set of eggs was inspected by the experimental system. This set was obtained from a highly automated egg farm. Number of eggs was 90 and eggs were selected to include a wide variety of weights ranging from Peewee to Jumbo size.

Algorithms

INSPECTION OF EGG SHELL

From the previous study by Cho and Kwon (1996), the optimum algorithm for crack detection was developed. The outline of algorithm is as follows: Isolation of the egg image from the rest of the background was performed by threshold value. The threshold value is automatically determined by the entropy method. The Sobel operator is then applied to enhance the egg image isolated from the whole image prior to segmentation. After enhancing the image, the cracks are isolated from the rest of the image by the thresholding. The threshold value is determined by Eq. (1);

$$T = 2.7032 \times G_m + 5.8749 \qquad (1)$$

where T is threshold value, G_m is average intensity.

To connect those disconnected pixels in the edges, 8 directional Laplacian filter which is the second derivative operator was applied before the crack detection. Then Freeman's directional chain code was used to compute the image features such as the perimeter and the area. The area and the roundness of features was used as the criteria to separate the crack and the translucent spots. The feature was regarded as a hole if the area was larger than 0.05 cm^2 and the feature was regarded as crack if the area was smaller than 0.65 cm^2 and the roundness was less than 0.3.

EGG SORTING

After the egg image was isolated from the rest of the background by thresholding, Freeman's directional chain code was used to compute the perimeter and the projected area of egg.

Experimental procedure

In the test, the eggs were placed above the lamp and the camera was set above the egg so that the images of the eggs fill the most of the display. The test involved placing an egg in the view of the camera and three images were taken at approximately 120 degrees intervals around the egg equator by manually rotating the egg. Cracked and crack-free eggs were placed randomly above the lamp. The program for capturing images, analyzing images and making a decision was written by C language. This program also includes the elapsed time measuring routine from the start of capturing images to finally report the shell status. Before inspecting of egg shell, all eggs were manually inspected whether they are cracked or not. In the test of egg sorting, crack-free eggs were used and weights of those eggs were measured by electronic balance. A half of samples were used to calculate the coefficients of multiple linear equation, this equation was used to estimate the weight of all samples. Then the estimated weight of eggs were sorted by the weight standard.

Results and Discussion

Inspection of Egg Shell

The results obtained from the system's ability test to correctly detect cracked eggs are shown in Table 2. The system correctly detected cracks in 102 out of the 105 cracked eggs tested. Two eggs had hair-line cracks and a egg had dirt-spots which the program failed to segment from the rest of the image as continuous line. All cases identified as cracked eggs was based on the actual crack instead of other defects. Ninety-five out of hundred-five eggs were correctly identified as crack-free. All of ten eggs were incorrectly identified as being cracks which had translucent spots in the egg shell. The system took approximately 1 min longer to analyze a crack-free egg than a cracked egg. Also the required times to analyze egg images were more variable. This result is attributed to the fact that the search for cracks ended when a crack was found and the number of translucent spots between uncracked eggs were various. The search continued until the entire image was scanned for the uncracked eggs. Figure 2 and 3 show the typical images of cracked egg before and after processing respectively.

Egg Sorting

The multivariable linear equation obtained from the half of samples were as following Eq. (2);

$$W = 5.374 \times A - 6.397 \times P + 42.995 \quad (2)$$

where W is the expected weight(g), A is the projected area (cm^2), and P is the perimeter(cm).

The coefficients of determination for the regression equation between weights and those two values were 0.99 in the two sets of experiment. Then, this equation then is used to calculate the weights of all samples. The results obtained from the system's ability test to correctly sort eggs are shown in Table 3. The system correctly sorted eggs in 87 out of the 90 eggs tested. The system took approximately 1 s longer to measure area and perimeter and to grade an egg.

Conclusions

1. With machine vision system, both the inspection of egg shell and egg sorting are found to be effectively performed.
2. The system correctly determined that an egg was cracked 97.1% of the time on the cracked eggs. The system correctly determined that an egg was not cracked 90.5% of the time on the uncracked eggs.
3. The average time required to detect cracks in cracked eggs was 40.5s and was 104.7s in uncracked eggs.
4. The detection of hair-cracks including other defects should be considered with faster processing in a further research.
5. The success rate of sorting was found to be 96.7% and the average time required to sort an egg was 1.1 s.

References

1. ARC Working party, 1982. "Sensors in Agriculture," *National Institute of Agricultural Engineering.* Wrest Park, Silsoe, Bedford.
2. Bourley, A.j. 1985. .Investigation of a robotic egg candling system.. *M.S. thsis(unpublished). Dept. of Electrical and Computer Engineering,* University of California, Davis.
3. Cho, H.K. and Y. Kwon. 1996. Crack Detection in Eggs by Machine Vision. 6th International Conference on Computers in Agriculture. 777-784. Cancun, Mexico. June 1996.
4. Cho, H.K. and Y. Kwon. 1995. Crack Detection and Sortings of Eggs by Image Processing. The Korean Society of Poultry Science 22(4):233-238.
5. Cho, H.K. and Y. Kwon. 1995. Detection of Surface Defects in Eggs Using Computer Vision. Journal of Korean Society of Agricultural Machinery. 20(4):368-375.
6. Data Translation, 1994. .Vision-EZ User Manual,. ;Frame Grabber Board for the IBM Personal Computer AT and the IBM Personal System/2, Data Translation, Inc.
7. Elster, R. T. and J. W. Goodrum. 1991. .Detection of cracks in eggs using machine vision,. *Trans. of the ASAE* 34(1):307-312.
8. Goodrum, J. W. and R. T. Elster. 1992. .Machine vision for crack detection in rotating

eggs,. *Trans. of the ASAE* 35(4):1323-1328.
9. Freeman, H. 1960. .On the encoding of arbitrary geometric configurations,. *IRE transactions on electronic computers*. 260-268.
10. Han, Y. J. and Y. Feng. 1994. .Egg shell inspection using global image analysis,. *Trans. of the ASAE* 10(1):109-114.
11. Jain, A. K. 1989. .Fundamentals of digital image processing,. *Prentice-Hall international, inc.*
12. Jain, A. K. and S. Ranganath. 1982. .Image rotation and edge extraction based on 2-D stochastic models,. *Proc. ICASSP-82, Paris.*
13. Miller, W. M. 1995. .Optical Defect Analysis of Florida Citrus,. *Applied Engineering in Agriculture,* Vol.11(6):855-860.
14. Roland, D. A., Sr. 1988. "Research Note: Egg shell problems: Estimates of incidence and economical impact," *Poultry Science* 67:1801-1803.
15. Worley, J. W. and J. W. Goodrum. 1995. .Strobe versus incandescent lighting for egg crack detection using machine vision,. *Trans. of the ASAE* 11(4) : 549-554.

Table 1. Specification of equipment

Elements	Specification
Main computer	IBM 486 DX2 (50Mhz), 8MB RAM, 827MB Hdd
Frame grabber	Data Translation DT-2855
Output unit	12 inch Monochrome display
Input unit	CCD camera, lens of 12 mm focal length
Lighting	Incandescent back lighting lamp

Table 2. Summary of result from testing the algorithm's ability to detect cracks in eggs.

Exp. No.	Type of Eggs	No. of Eggs	Eggs correctly analyzed (Number)	(%)	Elapsed Time (s)
1	Crack	35	34	97.1	41.3
	Crack free	35	32	91.4	105.9
2	Crack	35	34	97.1	40.2
	Crack free	35	32	91.4	104.6
3	Crack	35	34	97.1	39.7
	Crack free	35	31	88.6	103.6
Total	Crack	105	102	97.1	40.4
	Crack free	105	95	90.5	104.7

1. Highly automated egg producer
2. Conventional egg producer
3. Typical grocery store

Table 3. Summary of result from testing the algorithm's ability to sort eggs.

Grade	Standard weight (g)	No. of eggs by balance	No. of eggs by machine vision
Jumbo	Greater than 71	11	11
Extra Large	Less than 71	37	37
Large	Less than 59	16	15
Medium	Less than 53	23	26
Small	Less than 47	2	0
Peewee	Less than 41	1	1
Total		90	87
Accuracy(%)		100%	96.7%
Elapsed time(s)			1.10

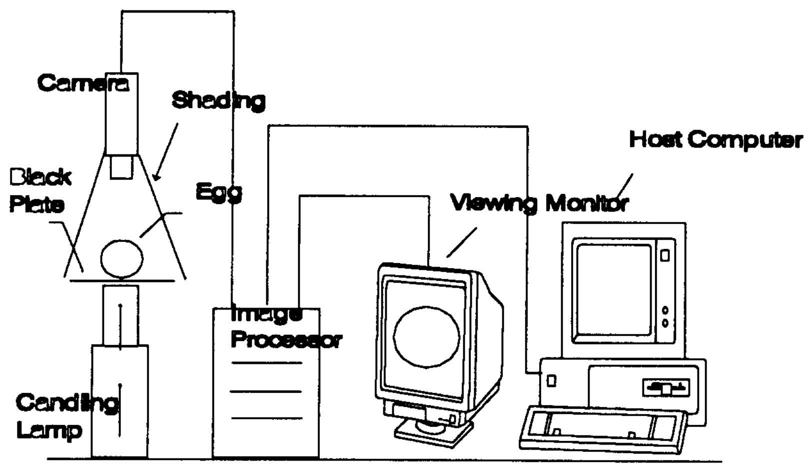

Figure 1. Schematic diagram of machine vision system

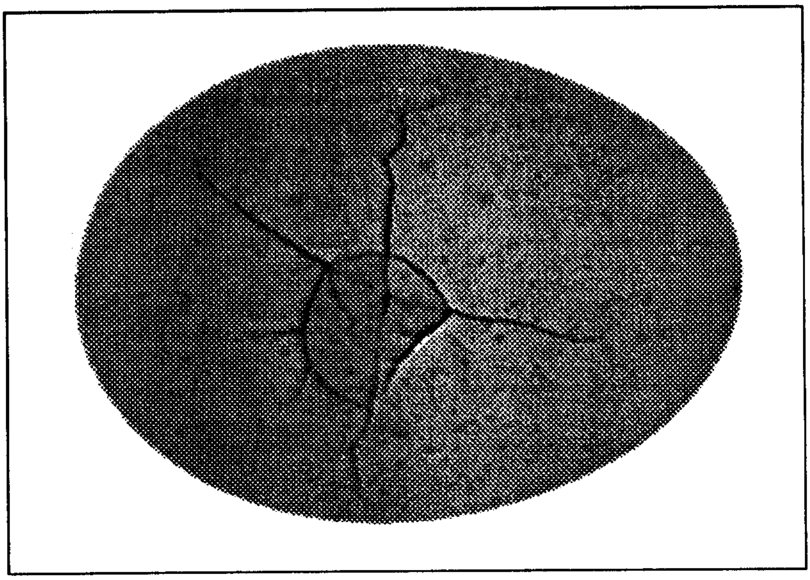

Figure 2. Image of cracked egg prior to image processing

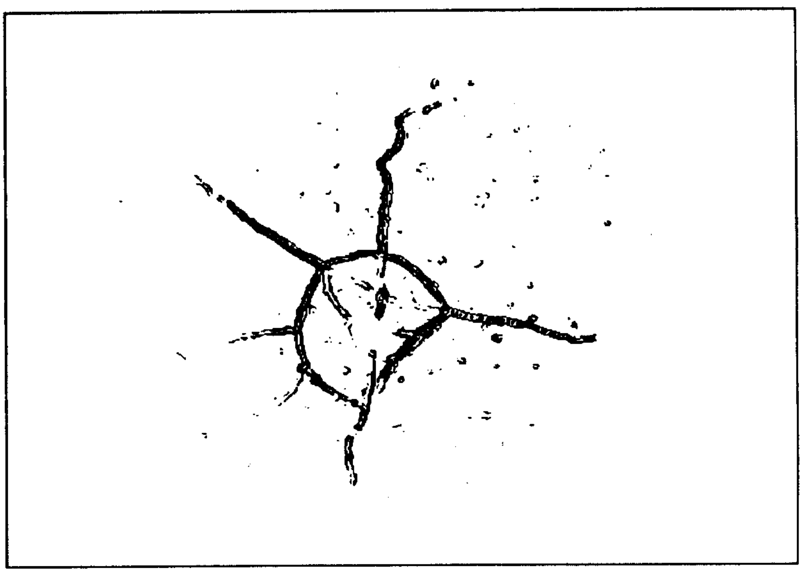

Figure 3. Image of cracked egg after to image processing