Identification of the hatching egg before the incubation based on hyperspectral imaging and GA-BP network

Zhihui Zhu[1, 2], Ting Liu[1, 2], Lirong Xiong[1, 2], Meihu Ma[1, 3*]

[1]*National R&D Center for Egg Processing, Huazhong Agricultural University, Wuhan, Hubei, China, 430070*

[2]*College of Engineering, Huazhong Agricultural University, Wuhan, Hubei, China, 430070*

[3]*College of Food Science and Technology, Huazhong Agricultural University, Wuhan, Hubei, China,* 430070

Received 26 August 2014, www.cmnt.lv

Abstract

The removal of the unfertilized egg from the hatching egg before the incubation could improve the efficiency of incubation. The identification of the unfertilized and fertilized eggs by hyperspectral imaging technology combined with GA-BP algorithm was proposed. The comparative analysis for the unfertilized and fertilized eggs was implemented by different pretreatment and principal component. In order to improve the performance of BP neural network, GA algorithm was used to optimize the network parameters. The application of GA-BP network was established the qualitative detection model. The results of the study showed that the MSC + SD pretreatment method was the most suitable for the model. The determination coefficient was 0.95, which indicated the optimized network model had a good generalization ability and high prediction precision with unfertilized eggs accuracy being 93%, fertilized eggs accuracy being 94%, the overall accuracy being 93.5%. The results indicated that the method of non-destructive identification for fertilized and unfertilized eggs based on hyperspectral imaging technology combined with GA-BP algorithm was feasible.

Keywords: hyperspectral imaging technology, before incubation, hatching eggs, identification, GA-BP

1 Introduction

Identification of unfertilized eggs before the incubation is one of the difficult problems in the hatchery industry, which has no reasonable solution yet. Hatchery statistics show that about 8%-9% of all incubated eggs do not hatch due to unfertilized eggs [1], which lead to huge waste of time, space, labour force and energy. In practical applications, candling eggs after 7 to 12 days of incubation are always used, but the pick-out unfertilized eggs have lost edible value, which lead to economic loss. The non-destructive identification of unfertilized eggs before incubation as early as possible can optimize space, save labour and energy, avoid contaminating of other eggs and bring better profits to hatcheries.

In recent years, many scholars have worked with the hatching eggs non-destructive detection using machine vision [2], acoustic pulse vibration [3], optical method [4], nuclear magnetic resonance imaging [5], hyperspectral and so on [6, 7], who have also made certain research progress, but mainly concentrated in the middle of hatching egg quality detection. Our group have used near infrared diffuse reflection for hatching egg quality detection [8], which made some achievements, but need to improve precision. High spectral technology as a new detection technology has a super multichannel, high spectral resolution, narrow band, wide spectral range. It is the perfect combination of image and spectrum technology, which can obtain both image information and spectral information. So more and more people get the attention of hyperspectral image technology in non-destructive testing of the quality of agricultural products, especially widely used in detecting the quality and safety of livestock products, fruits and vegetables [9, 10]. In recent years, some scholars used hyperspectral image technology for detection of unfertilized and fertilized eggs, but they are mainly research on the detection during the early period. The main purpose of this study was to explore the feasibility of hyperspectral image technology on the unfertilized and fertilized eggs detection before the incubation.

2 Materials and method

2.1 EGG SAMPLES

Two hundred eggs including 100 fertilized eggs and 100 unfertilized eggs were collected from Huazhong Agricultural University Hatchery within one week, which were obtained from 50-55-wk-old Single Comb White Leghorn chickens. We randomly chose, for each class, 60% of the subset to build the training set (60 fertile eggs and 60 infertile eggs) and the remaining 40% was put aside for testing set (40 fertile eggs and 40infertile eggs). Corresponding training set and testing set were 120 and 80 samples respectively. After cleaned, all the samples were numbered.

Corresponding author e-mail: zzh@mail.hzau.edu.cn

2.2 TESTING SYSTEM

The Headwall Hyper spectral imaging spectrometer (HS-VNIR N-series) was used, which had 400 nm to 1000 nm spectral range. The hyperspectral image acquisition system was shown in Figure 1. In order to ensure that the sample uniform illumination, six halogen tungsten lamp (Philips, 35W) were displaying asymmetric distribution to form DC circular lighting system. The main working parameters were set as following: the exposure time was 5 ms; the interval of the conveyer was 120 µm; spectrum sampling interval was 0.8 nm; scanning length was 70 mm.

ENVI V. 4.3 (Research System, Inc., USA) and MATLAB V. 7.0 (MathworksCo., USA) software were used to process the data of hyperspectral image. Hyperspectral images were 3D data blocks, each pixel in the image corresponded to one spectrum. 10556 pixels of the elliptical area of egg image were selected to be region of interest (ROI) (the green part in the Figure 2a). The average of the spectrum, which was obtained by the calculation of all pixels in the ROI, was regards as the reflection spectrum of eggs (the white part in the Figure 2b).

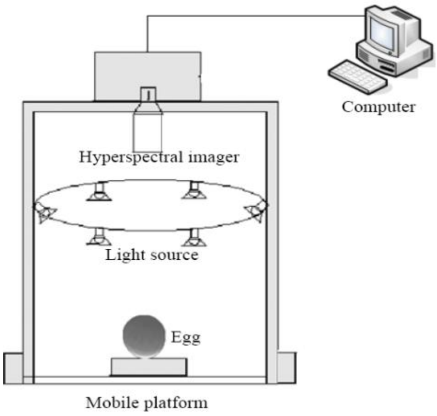

FIGURE 1 Hyperspectral imaging system

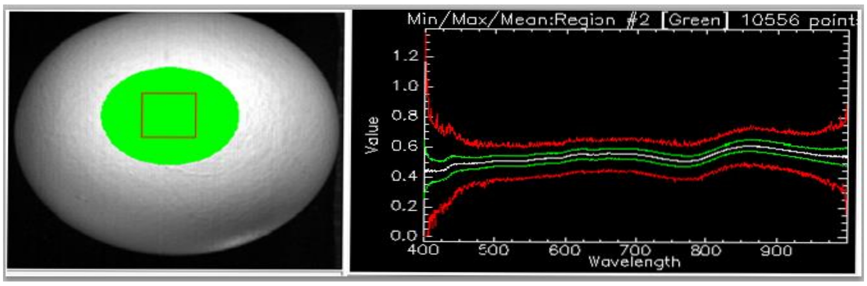

FIGURE 2a Marking of ROI FIGURE 2b Spectral information of ROI

2.3 THE CALIBRATION OF IMAGES

The uneven light intensity distribution and dark current noise, which existed in the working process of hyperspectral image acquisition system, would cause that the image with the weak light intensity distribution of band contained larger noise. Therefore black and white calibration should be implemented for the hyperspectral image [11]. Before collecting all sample images, the black calibration image *B* was collected with covering lens, and white calibration image *W* was collected by scanning calibration standard white plate, then according to the formula (1), absolute image *I* was converted relative image *R*.

$$R = \frac{I - B}{W - B}. \quad (1)$$

2.4 EGGS ASSESSMENT

The eggs were sent to incubator for hatching after scanned by hyperspectral image acquisition system. The incubator was sterilized by formaldehyde solution fumigation and worked for 24 hours in predefined temperature and humidity conditions before the eggs were put in. The incubator temperature was 38.5 ℃ and the relative humidity was 65%. It was difficult to distinguish unfertilized eggs from fresh hatching eggs by their morphology. Only after hatched for four days, they could be distinguished by candling. The fertilized eggs would appear blood spots through candling in the fourth day, at the same time, unfertilized eggs had no embryonic development phenomenon. According to candling at the fourth day, the actual type of unfertilized eggs and fertilized eggs were determined. If it could not be distinguished clearly, the egg would be broken and observed whether the embryo has developed or not.

2.5 GA-BP NETWORK ALGORITHM

Back-Propagation (BP) neural network has strong nonlinear mapping ability and flexible network structure. But it is easy to fall into local minimum, slow convergence speed and so on. Genetic algorithm (GA) is a kind of adaptive global optimization probability search algorithm based on natural selection in the formation of biological and genetic processes. GA was used to optimize the initial weights and threshold of BP neural network. The optimal initial weights and thresholds were obtained through selection, crossover and mutation operation of GA, which could overcome the random defects of connection weights and thresholds of BP neural network [12]. GA-BP neural network not only played the mapping ability of BP neural network generalization, but also made BP neural network has fast convergence and strong learning ability. The specific algorithm flowchart was shown in Figure 3.

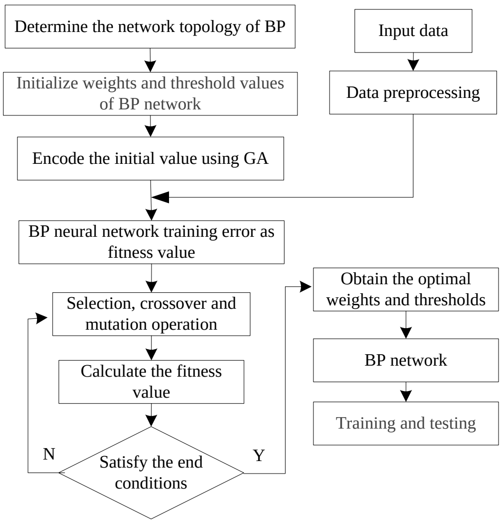

FIGURE 3 The flow chart of GA-BP neural networks

3 Results and discussion

3.1 PREPROCESSING AND DIMENSIONALITY REDUCTION

The spectrum extracted from eggs contained not only the information of the eggs themselves, but also information and noises from eggshell, background and instruments. Therefore, some pretreatments must be taken for the egg spectra to remove the useless information. In this paper, 10 kinds of pretreatment methods were used for the spectra data, which included the first order derivative(FD), the second order derivative (SD), multiplicate scatter correction (MSC), the standard normalization(SNV) and the combination of MSC+FD, MSC+SD, SNV+FD, SNV+SD, FD+SM, SD+SM. The following only gave the original spectra (Figure 4) and pre-treated spectra with MSC+SD (Figure 5). From Figure 4, two kinds of egg original spectra had the same general trend and small differences, while after pretreatment (Figure 5), the features of image peaks and valleys, lifting trend were more obvious. At the same time, the differences of fertilized and unfertilized eggs in some range of peaks and valleys were widened so that it was easier to distinguish them. Further it could be seen that the original spectral values range in each band was larger, but the spectral values of the samples after the pre-processing were concentrated in a small interval, which made the feature more obvious and was beneficial to classification. After analysis and comparison, it could be seen that the differences of spectra between the fertilized and unfertilized eggs were mainly concentrated within the wavelength range of 400 nm~500 nm, 700 nm~900 nm.

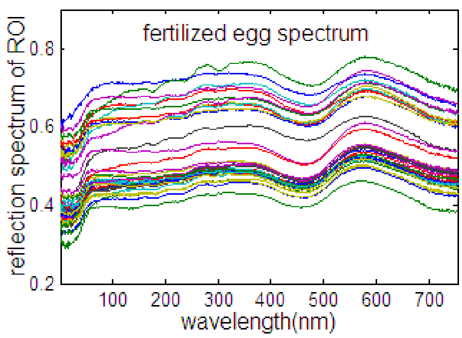

FIGURE 4a Spectrum of Fer.

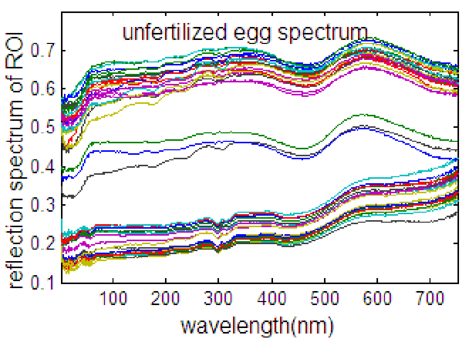

FIGURE 4b Spectrum of Unfer.

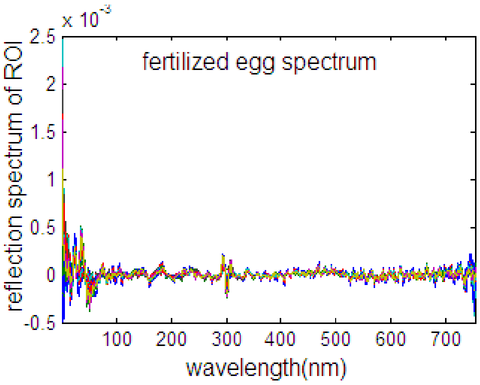

FIGURE 5a Fer. spectrum after MSC+SD

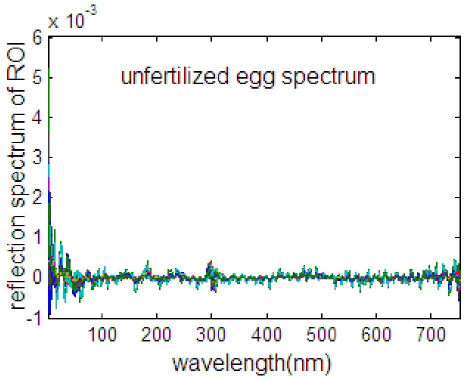

FIGURE 5b Unfer. spectrum after MSC+SD

Note: Fer. means fertilized egg; Unfer. means unfertilized egg

TABLE 1 Number of principal component by various spectroscopic data pre-processing

PM	FD	SD	SNV	MSC	MSC+FD	MSC+SD	SNV+FD	SNV+SD	SM+FD	SM+SD
NPC	4	7	3	2	4	7	4	7	4	6

In order to reduce the dimension of hyperspectral data, principal component analysis (PCA) was used to analysis above ten kinds of pretreatment of spectrum respectively. When the cumulative contribution rate of the eigenvalues of the covariance matrix exceeded 90%, the corresponding principal components were selected. The statistical results were shown in Table 1. From Table 1, it could be seen that the number of the variables were greatly reduced by using PCA so that it could improve of training speed and precision of the neural network model.

3.2 CLASSIFICATION OF BP NETWORK

BP neural network was worked as a classifier in this experiment. The 200 samples were randomly divided into a training set and a test set. First, the data that was pretreated in different ways should do principal component analysis. The principal component variables instead of the original variables were used as the input of the neural network, and then built the BP neural network for training. The training times was 2000; error performance objectives was 10^{-4}, and the learning rate was 0.01. The average of accuracy and coefficient of determination was used to evaluate the neural network in the number of this hidden layer. The programs had run 10 times and the results were shown in Table 2. As could be seen from Table 2, the model worked best after MSC + SD data preprocessing. So MSC + SD could be determined as the best pretreatment way. Corresponding network structure were one hidden layer and three hidden layer nodes. But average accuracy rate of the network prediction was only 83% and decision coefficient is only 0.57 after the optimal pretreatment. Also, classification accuracy of the network was not satisfactory. In the absence of initial weights threshold value, BP network were randomly assigned to each training weights threshold, causing instability in the models and turbulence in the training results. Therefore, it was necessary to further optimize the parameters of the network in order to improve the network performance.

TABLE 2 Model performance of various pre-processing pattern

PM	FD	SNV	MSC	SD	MSC+FD	MSC+SD	SNV+FD	SNV+SD	SM+FD	SM+SD
NPC	4	3	2	7	4	7	4	7	4	6
DC	0.53	0.53	0.43	0.41	0.44	0.57	0.51	0.56	0.56	0.44
PA	82%	86%	66%	74%	76%	83%	82%	83%	84%	74%

Note: PM means Pretreatment Methods; NPC means Number of Principal Component; DC means Determination Coefficient; PA means Prediction Accuracy

3.3 GA-BP NETWORK OPTIMIZATION

The neural network structure that previously constructed was established by the 7-3-1. The total number of weights was 24(7 * 3 + 3 * 1 = 24) and the total number of threshold was 4(3 + 1 = 4), so the encoding length of individual of genetic algorithm was 28 (24 + 4 = 28). We randomly chose from original training set of 120 samples, for each class, 80 eggs of original training set to build the training subset (40 fertile eggs and 40 infertile eggs) and the remaining all was put aside for testing subset (20 fertile eggs and 20 infertile eggs). The absolute value of the training data prediction error was regard as the individual fitness value, the smaller the fitness value, the more preferably individuals.

The genetic algorithm parameters were set as follows: population size was 10, evolution was 100 times; crossover probability was 0.4; the variation coefficient was 0.2. In the process of the genetic algorithm to optimize, the best individual fitness value changed as shown in Figure 6.

The optimal weight and threshold value of BP neural network were obtained by the genetic algorithm, which were shown in Table 3.

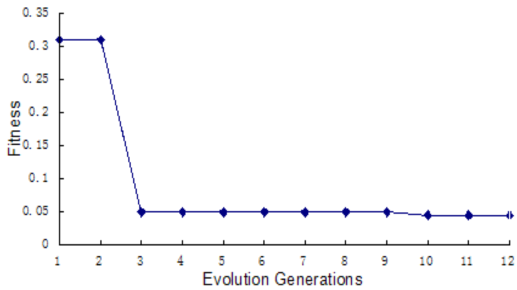

FIGURE 6 The best single adaptive by GA

TABLE 3 The best weights and threshold of BP net optimized by GA

Weights between input layer and hidden layer			**Hidden layer node threshold**	**Weights between hidden layer and output layer**	**Output layer node threshold**
-2.2145	-0.9389	0.9784	2.7922	-2.0859	-2.8262
0.0972	1.78	0.4596	-1.0909	-0.6995	
-2.5988	-1.5093	2.4521	2.7336	-2.9215	
2.3371	2.9388	-1.0581			
2.9245	0.6832	0.9125			
0.6081	1.7868	0.6627			
-0.7366	-1.9521	-2.6405			

3.4 TESTING OF OPTIMIZED BP NETWORK

The optimized BP network was used to test the 80 samples of original test set. Ten replicates were performed. Table 4 showed that using the BP network model predicted 10 times of classification accuracy and determination coefficient. It could be seen that unfertilized egg accuracy was 93%; fertilized eggs accuracy was 94%; among the 10 replicates testing, the extreme maximum accuracy of fertilized and unfertilized egg was 100% and 97.5% respectively; the extreme minimum accuracy of fertilized and unfertilized egg was 90% and 87.5% respectively; the overall accuracy of 93.5%, and the determination coefficient was 0.95. The result showed the network had high prediction precision and good generalization ability.

TABLE 4 The prediction results by 10 times tests

Egg type	**Extreme maximum accuracy**	**Extreme minimum accuracy**	**Average accuracy**	**Total accuracy**	**Determination Coefficient**
Fertilized egg	100%	90%	94%	93.5%	0.95
Unfertilized egg	97.5%	87.5%	93%		

4 Conclusions

In this research, an attempt has been made to preprocess spectral data, reduce data dimension and classify the unfertilized eggs using GA-BP network. Classification accuracy was 93.5%, which was encouraging. The results showed that MSC+SD pretreatment method was the most suitable for the model, PCA reducing data dimension was effective and hyperspectral technology combined with GA-BP network to identify unfertilized eggs and fertilized eggs was feasible.

Acknowledgments

This work was supported by Special Fund for Agro-scientific Research in the Public Interest(Project Code No. 201303084), the Fundamental Research Funds for the Central Universities of Huazhong Agriculture University (Grant No. 2662013JC005), Natural Science Foundation of Hubei Province of China (Grant No.2011CDB137) and the National Natural Science Foundation of China (Grant No. 51105160). The authors would like to thank the reviewers of this paper for their constructive comments and advice, which greatly helped us to improve the quality of the paper.

References

[1] Das K, Evans MD 1992 Detecting fertility of hatching eggs using machine vision I: Histogram characterization method *Trans. ASABE* **35**(4) 1335–41
[2] Wang Q H, Ma M H, Zhu Z H, Zhu T, Li M 2012 Non-destructive Detection of Hatching Egg's Survival Based on Machine Vision *Journal of Food, Agriculture & Environment* **10**(1) 578-81
[3] Coucke P M, Room G M, Decuypere E M, de Baerdemaeker JG. 1997 Monitoring embryo development in chicken eggs using acoustic resonance analysis *Biotechnology Progress* **13**(4) 474-8
[4] Bamelis F R, Tona K, De Baerdemaeker J G, Decuypere E M 2002 Detection of early embryonic developmentin chicken eggs using visible light transmission *British Poultry Science* **43**(2) 204-12
[5] Klein S, Rokitta M, Baulain U, Thielebein J, Haase A, Ellendorff F 2002 Localization of the fertilized germinal disc in the chicken egg before incubation *Poultry Science* **81**(4) 529-36
[6] Smith D P, Lawrence K C, Heitschmidt G W 2008 Fertility and embryo development of broiler hatching eggs evaluated with a hyperspectral imaging and predictive modeling system *International Journal of Poultry Science* **7**(10) 1001-4

[7] Zhang W, Pan L Q, Tu K, Zhang Q, Liu M 2014 Comparison of spectral and image morphological analysis for egg early hatching property detection based on hyperspectral imaging *PLOS ONE* **9**(2) 1-10

[8] Zhu Z H, Wang Q H, Wang S C, Dai M Y, Ma M H 2012 The detection of hatching eggs prior to incubation by the near infrared spectrum *Spectroscopy and Spectral Analysis* **32**(4) 962-5

[9] Lu R F 2007 Nondestructive measurement of firmness and soluble solids content for apple fruit using hyperspectral scattering images *Sensing and Instrumentation for Food Quality and Safety* **1**(1) 19-27

[10] Naganathan G K, Grimes L M, Subbiah J, Calkins C R, Samal A, Meyer G E 2008 Partial least squares analysis of near-infrared hyperspectral images for beef tenderness prediction *Sensing and Instrumentation for Food Quality and Safety* **2**(3) 178-88

[11] Zhao J W, Wang K L, OuY Q, Chen Q S 2011 Measurement of chlorophyll conent and distribution in tea plant's leaf using hyperspectral imaging technique *Spectroscopy and Spectral Analysis* **31**(2) 512-5

[12] Pan H 2005 Application of BP neural network based on genetic algorithm *Computer application* **25**(12) 33-45

Authors

Zhihui Zhu, born in April, 1975, Hubei, P.R. China

Current position, grades: associate professor.
University studies: PhD degree in electrical engineering and automation, Wuhan University in 2008.
Scientific interest: nondestructive testing of agricultural products.
Publications: 20 papers.
Experience: teaching experience of 6 years, 3 scientific research projects.

Ting Liu, born in August, 1987, Hubei, P.R. China

Current position, grades: postgraduate student.
University studies: Huazhong Agricultural University.
Scientific interest: nondestructive testing of agricultural products.
Publications: 2 papers.
Experience: teaching experience of 1 year, 3 scientific research projects.

Lirong Xiong, born in January, 1977, Hubei, P.R. China

Current position, grades: associate professor.
University studies: PhD degree in agricultural engineering, Huazhong Agricultural University in 2010.
Scientific interest: nondestructive testing of agricultural products.
Publications: 20 papers.
Experience: teaching experience of 4 years, 3 scientific research projects.

Meihu Ma, born in June, 1957, Hubei, P.R. China

Current position, grades: professor, vice president of College of Food Science and Technology, Huazhong Agricultural University.
University studies: PhD degree in food engineering, Hunan agricultural University in 2005.
Scientific interest: food science.
Publications: 100 papers.
Experience: teaching experience of 10 years, 3 scientific research projects.