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Full Length Research Paper

Non-destructive detection of Sudan dye duck eggs based on computer vision and fuzzy cluster analysis

Tao Zhu and Qiaohua Wang*

College of Engineering, Huazhong Agricultural University, Wuhan, 430070, P.R. China.

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A method of non-destructive detection of Sudan dye duck eggs was developed using image processing and fuzzy cluster analysis. Duck egg color images were obtained by using a computer vision device. Through the component analysis of RGB image, it was found that the yolk region could be viewed distinctly in the gray scale image of B-component, and this characteristic was used to separate the yolk region from the white region. By extracting and comparing the color parameters, the R-component values of the yolk region showed obvious differences for Sudan dye and natural red-yolk duck eggs. A fuzzy discriminant model for the detection of Sudan dye duck eggs was established using the yolk's color parameters. The experimental results indicated that this model had good capability of identification for Sudan dye eggs.

Key words: Duck egg, Sudan dye, computer vision, fuzzy cluster analysis, non-destructive detection.

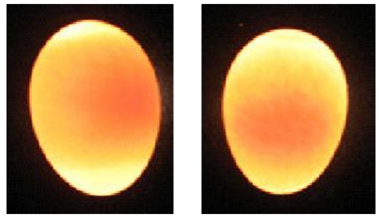
INTRODUCTION

Egg yolk or the yellow part of an egg is considered to be a rich source of nutrients, which is vital for health and maintenance of one's body. The yolk color of eggs naturally varies from pale yellow to yellow-red, produced by carotenoid pigments, especially by xanthophyll which is present in the natural poultry feeds like maize, lucerne, grasses, tomatoes, carrots, algae etc. Richer-colored egg yolks are more likely to come from free-range ducks, since they have the opportunity to eat more pigmented foods, and the pigment is then transferred to the yolk. In china, it is said that the redder the egg yolk is, the more nutrient it contains. As we know, the so-called RED-YOLK EGG is popular widely, and it has a good sale and high price.

In order to get more RED-YOLK EGGS, that is to say, to make the eggs become more popular among our customers for their yolk color, we can add carotenoid into the feeds of poultries. There are 8 kinds of colorants allowed to be added into the feeds in China. These colorants can cause the colors of eggs and meat to be transformed into bright red and yellow. They are not harmful, but even beneficial to human health. However, these colorants that are allowed and encouraged are costly to usual keepers. Considering the egg yolk, which is apt to gather color agents, many keepers use one cheap but toxic industrial chemical dye--Sudan, which is a fat-soluble substance that is appropriate to gather in high- protein and high-fat substances in the region of egg yolk. So, Sudan was added into the feed of poultries in recent years; and then a number of RED-YOLK EGGS containing Sudan appeared in the market later on.

Toxicology study shows that Sudan, a sort of industrial chemical synthesis of AZO dyes can never add into any food for its characters of mutagenicity, carcinogenicity, genotoxicity and allergenicity. If some do it, there must be a high rate of liver cancer incidence. It is forbidden in plaintext that Sudan is added into food in China. In order to prevent food containing Sudan entering the food market, strict rules and regulations are set to test and control the content of Sudan in food by every quality supervision department. Various methods, such as HPLC-UV (DAD) or HPLC-MS (MSn), were developed for the detection of the Sudan dye (Yuetong, 2007;

*Corresponding author. E-mail: wqh@mail.hzau.edu.cn. Tel: 1340 7166- 099.



a b

Figure 1. Egg images. (a) Sudan dye egg and (b) Natural egg.

Menghua, 2007; Yinliang, 2008; Wei, 2008; Li et al., 2010; Lichuan, 2010; Rebane, 2010). All these belong to destructive detection methods with the tested eggs being broken. It is clear that destructive detection methods have many shortages, such as long period, high rate of loss, complexity of the program and variety of reagents. In other words, destructive detection methods are verbose and time-consuming, which are far more beyond the demands of modern detections. This paper proposed a new non-destructive detection method for Sudan dye duck egg based on computer vision, and gave the relationship between the quality and image information parameters of Sudan dye duck egg.

MATERIALS AND METHODS

Duck egg samples

(1) Ten matured ducks and a little industrial dye Sudan with 46.5% were prepared.
(2) Feed recipes: One was natural, containing 1/3 small fish and shrimps, 1/3 yellow corn grains and carrot chops and 1/3 millet. Another contained common millet and 2 g Sudan per 10 kg millet in it.
(3) Ten ducks were divided into two groups. They were fed different feeds for 20 days, and then the eggs from each duck group were respectively collected.
(4) The "collected" eggs were marked and kept fresh in the fridge as samples.

Image acquisition

A computer vision system for image acquisition was set up, which consisted of a digital camera (Canon Power Shot A640), a computer, a transformer (TDGC2-0.05, Range: 0~250V), an incandescent lamp (40 W) and a special box for image capture. The detailed description for this system can be found in our previous work (Qiaohua Wang et al., 2009). Images were obtained after the egg samples were arranged into this system. A group of white-shell duck egg image was obtained as shown in Figure 1, which is one of the 18 groups.

RESULTS AND DISCUSSION

Image processing

Many factors affected the image information and the characteristic parameters, such as vision device factors, the light, the background, the photographing technology, etc. That is to say, the original images from the vision's device are with many noises and lack distinct characteristics. Most Sudan existed in yolk, but the egg yolk could not be seen in the egg image (Figure 1); therefore the obtained original egg images must be processed variedly for separating the yolk from the egg white.

MATLAB was used to process the original image in this paper. First, image input was used, followed by image cut, and then the image type conversion. The egg yolk could not be seen in the original egg image (Figure 1). In this research, the three- components of R, G and B were separated from the egg color picture and then the color picture was converted into a gray scale image for finding the feature region of the egg yolk. The gray scale image and its histograms for the R, G and B components were shown in Figure 2. It was found that the yolk could only be viewed distinctly in the gray scale image of B-component and the whole image was dark somewhat.

An image histogram is a type of histogram which acts as a graphical representation of the tonal distribution or the gray scale density approximation in a digital image. For gray scale image, the histogram is a discrete function, and it plots the number of pixels for each tonal value. By looking at the histogram for a specific image, one will be able to judge the entire tonal distribution at a glance. In this research, the histogram was used to get some important information such as the overall bright level, the contrast ratio and the reparability of the object. This valuable information can help us to understand what we need in the picture. This is also essential as the basis of image processing. Histograms equalization can make one narrow gray scale region wider, extend the dynamic range of the pixel values and enhance the contrast ratio. Hence, it is used to reveal the slight gray scale in a narrow region.

Histograms equalization for B-component was shown in Figure 3. The yolk and egg white was distinctly distinguished, so as to set a reasonable threshold value and obtain a distinct B-component equalization binary image. B-component equalization binary image was filtered, while the dilation operations of the mathematical

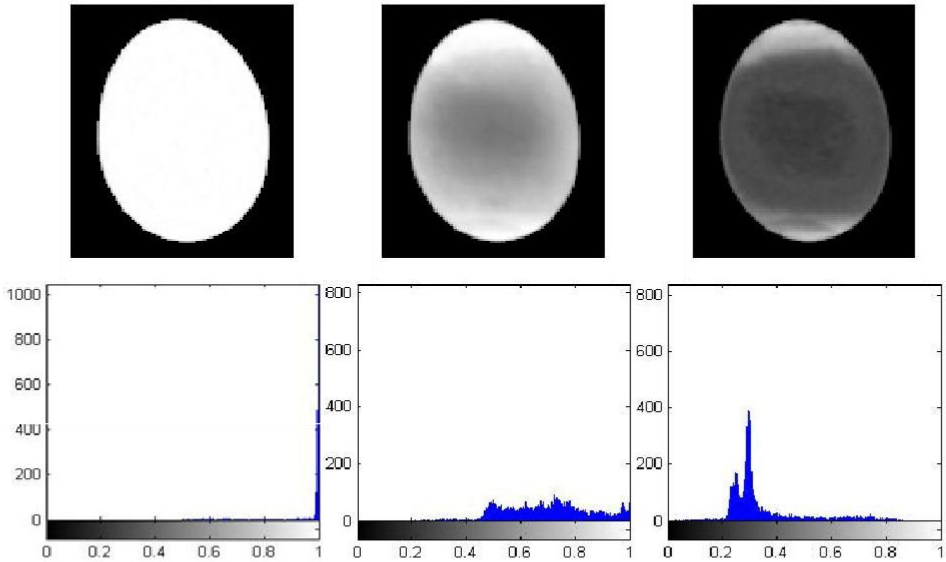


Figure 2. The gray scale image and its histograms for the R, G and B components (from left to right).

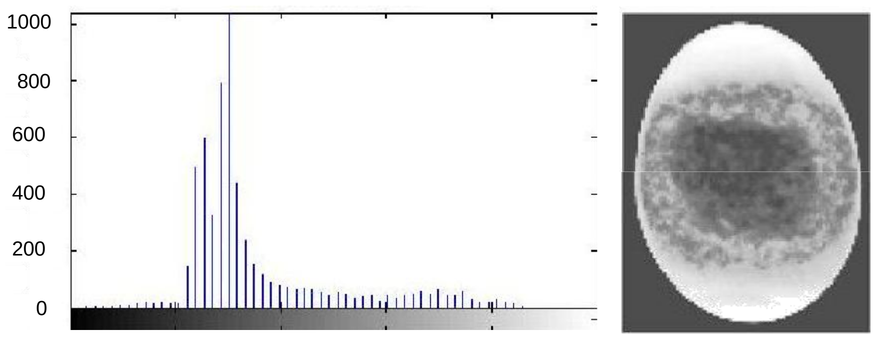


Figure 3. Histograms equalization for B-component.

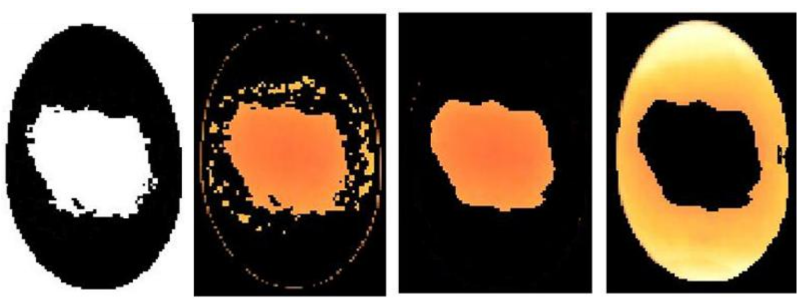


Figure 4. Separation of the egg yolk and egg white.

morphology were experienced, and the noise was removed. Then the distinct yolk image was gotten. After the steps were shown, the yolk binary image was eliminated from the whole egg binary image, and then the binary image of the egg white was left. Separation of the egg yolk and egg white was shown in Figure 4.

Color feature extraction

The R, G and B component values of the two kinds of duck egg yolk were acquired respectively. Then they were changed into H, S and I values. Through contrastive analysis to the information, it could be found that there

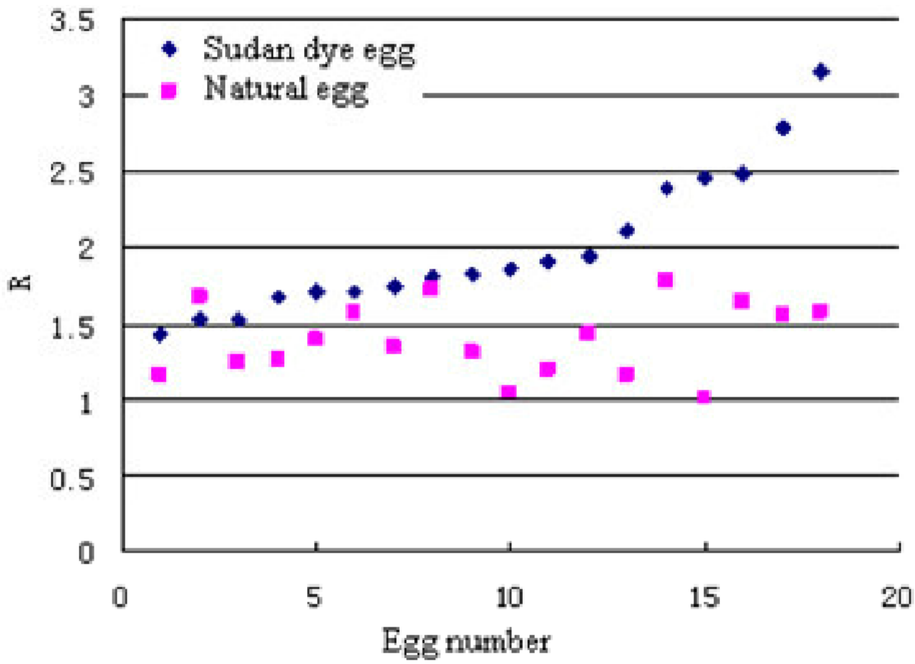


Figure 5. The scattered diagram of the two kinds of eggs.

was great difference between the two R-component values of the two kinds of duck eggs' yolk. However, the scattered diagram was shown in Figure 5.

Modeling

Fuzzy cluster analysis

Cluster analysis is a technique used for classifying data, that is, to divide a given dataset into a set of classes or clusters. Fuzzy cluster analysis is a mathematical way of assorting the objects based on the relationship degree or similarity of the data. Most fuzzy clustering algorithms are objective function based, that is, they determine an optimal classification by minimizing an objective function.

For an arbitrary element x in the discourse domain and the field of research U, if there is one value A(x) satisfying 0 A(x) 1, then A is the fuzzy set of U, and A(x) is the degree of membership for x belonging to A. When x changes in U, A(x) is a function called membership function. If the degree of membership A(x) is more close to 1, the more x will belong to A. In contrast, if A(x) is more close to 0, the less x will belong to A. Membership function A(x) on the closed interval 0 A(x) 1 is employed to characterize the degree of membership between x and A. For our problem, the fuzzy analysis method is more reasonable than the classical set theory (Jijian and Chengping, 2000).

In this work, the maximum membership principle is used to establish the fuzzy recognition model:

Given m fuzzy subsets as $A_1, A_2, \cdots, A_m$, a standard model base is formed. For each element in U, there is a value $i_0 \in \{1,2,\cdots,m\}$ such that

$$A_{i_0}(x_0) = \vee_{k=1}^{m} A_k(x_0),$$

then x_0 relative belongs to A_{i_0}.

Duck egg classification modeling

In Figure 5, the R-component of two kinds of eggs with good separation can be used to construct the cluster analysis model. According to extracted data, the range of Sudan's R-component is on the open interval (1.43 and 3.15), and the range of the natural egg is (1.17 and 1.58). It can also be found from Figure 5 that the R -components of eggs containing Sudan are relatively higher and more decentralized than the one of the natural egg. Even the R-components of natural eggs with red yolk are also relatively lower than 1.58. However, there is a coinciding field around 1.5. Based on the R-component feature, the fuzzy cluster analysis used for recognizing the Sudan dye duck is appropriate.

Let the universal set U = {All the duck eggs}, and the two fuzzy sets be realized as: A = {natural eggs} and B =

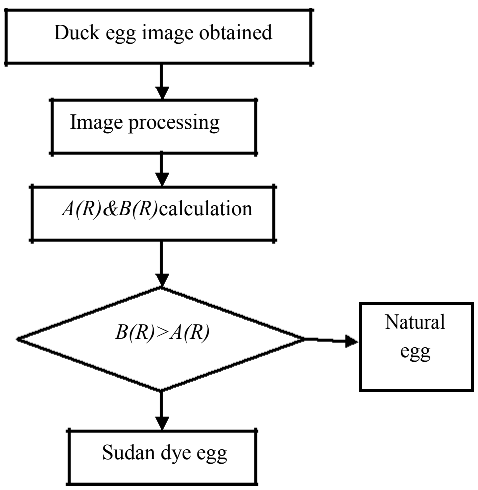


Figure 6. The test flow chart.

{Sudan dye eggs}. Based on the assignment method, the membership function of A and B can be constructed as follows:

$$A(R) = \begin{cases} 0 & R > 3.15 \\ \dfrac{3.15 - R}{3.15 - 1.43} & 1.43 \le R \le 3.15 \\ 1 & R < 1.43 \end{cases} \quad (1)$$

$$B(R) = \begin{cases} 0 & R < 1.43 \\ \dfrac{R - 1.43}{1.58 - 1.43} & 1.43 \le R \le 1.58 \\ 1 & R > 1.58 \end{cases} \quad (2)$$

For detection, we submit the R value of the duck egg into the two formulas. According to the principle of maximum membership, if B(R)>A(R), the egg is assumed to contain Sudan, otherwise it is a natural egg.

Model testing

In order to test the veracity and relationship of this model, the same experiment was taken using the other two group duck eggs, that is, 15 eggs for each group. The test flow chart which is shown as Figure 6, include image acquisition, image processing, parasitic extraction and calculation, model substitution and comparing the computing result. It can be found that 26 eggs have been tested correctly, that is to say, the accuracy rate is nearly 87%. It indicates that this method is feasible.

Conclusions

(1) Sudan dye duck egg, which has a slightly bigger R value than that of nature eggs, can be detected through computer graphics technology. Through the experimental study, this paper verifies the feasibility of using the principle of maximum membership to detect Sudan dye duck egg.
(2) The conclusion is based on experiments and it can be more precise if the computer vision systems can be improved.
(3) Raising a large number of duck eggs is impossible because of the strict requirement for feeding environment. Besides, since there is a period when ducks do not lay eggs, the sample of duck eggs is not large enough and as such, making a large quantity of repeated trials is not feasible. Therefore, the results may be fortuitous.

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