

EGG VOLUME AND SURFACE AREA CALCULATIONS BASED ON MACHINE VISION

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Abstract: Egg volume(V) and surface area(S) are two important geometrical calculations for the poultry industry and in biological studies, as they can be used in research on population and ecological morphology, and to predict chick weight, egg hatchability, shell quality characteristics, and egg interior parameters. With machine vision technology, the objective of the research herein was to develop a much more fast and available method to predict them. Besides, the researcher gave the definition of Volume in Pixels (V_p) and Surface area in Pixels (S_p) for the first time. Finally, new linear models were established. The R value for volume model is 0.88 and surface area is 0.86. The prediction ability of the models are: for volume, the correctness reaches 52% with $\pm 1\text{cm}^3$ statistical errors, 89% with $\pm 2\text{cm}^3$, for surface, the correctness reaches 49% with $\pm 1\text{cm}^2$ statistical errors, 87% with $\pm 2\text{cm}^2$.

Keyword: Egg, Volume, Surface area, Machine vision

1. INTRODUCTION

Egg volume and surface area are important geometrical calculations in poultry studies, which were reported by Narushin(2001b,2002,2002a,2002b). So how to measure them quickly and accurately is considered to be a hot topic. As far as so on, several models, based on the measurements of the egg length (L) and the maximum breadth (B), have been suggested to calculate the parameters. The basic formula for calculating egg volume was:

$$V = k_v LB^2, \quad (1)$$

in which k_v is a coefficient for volume calculation. The coefficient values were firstly reported by Romanoff(1949). Later, data gave $k_v=0.523$ (Ayupov,1976), and $k_v=0.496$ (Narushin, 1997a), and a number of values of k_v were proposed by Hoyt(1979). Narushin(2001a) showed that egg volume can also be estimated by means of a theoretically deduced formula:

$$V = \frac{2\pi L^3}{3(3n+1)}, \quad (2)$$

in which $n = 1.057\left(\frac{L}{B}\right)^{2.732}$.

Later, Narushin(2005) gave a more accurate and available formula than ever before:

$$V = (0.6057 - 0.0018B)LB^2 \quad (3)$$

Similar to equation(1) and taking into account the changes of the dimensionalities, the lasted formula for calculating S were reported by Narushin(2005):

$$S = (3.155 - 0.0136L + 0.0115B)LB \quad (4)$$

However, there are still several problems: firstly, the supposed curve in the reported models(taking Narushin,1997's for example) will not always best resemble all eggs' shapes; secondly, if thus, the measurements of L and B with a vernier caliper can't be fast and automatic, which will not be acceptable in poultry industry.

Thus, with machine vision technology, the objective of the research herein was to develop a much more fast and available method to solve the above problems. Characteristic parameters firstly defined by the researcher were calculated from the edge information detected from the egg image. Besides, new linear models were built to predict the volume and surface area based on the calculated parameters.

2. MATERIAL AND METHODS

2.1 Egg samples

In this experiment, 100 fresh eggs were collected from hens of 70 weeks old raised by Hubei Xiantao Food Corporation in China. They were labeled in order after cleaning and air-drying.

2.2 Experimental system

As shown in Fig.1, the test system was composed of lamp(DPS-24W30-4T), CCD camera(SRC-500HP), Additional Lamp, Image Card(DH-VRT-CG200), Computer, and etc.

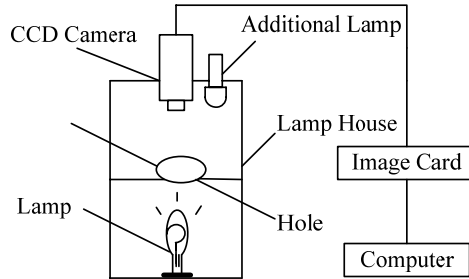


Fig.1 the test system

2.3 Experimental Method

2.3.1 Specific procedure

The experiment should be executed through these steps: (i) put each egg on the hole, through where the light can shine out, and (ii) adjust the direction of egg till the projection of longitudinal axis in the image was vertical in the screen(manual viewing the screen while adjusting), then capture the image and store it in the harddisk, and (iii) with the self-developed programme, detect the edge information, later, calculate the characteristic parameters of volume in pixels(V_p , unit: p_{ix}^3 , p_{ix} =pixel) and surface area in pixels(S_p , unit: p_{ix}^2), which were explained in the next paragraph, and (iv) calculate the exact volume V and V_s using the difference between the measurements of egg weight in air and water, and finally calculate the exact surface area S from the formula:

$$S = \frac{V_s}{T_s} \quad (5)$$

where V_s is the volume of the eggshell, T_s the average thickness of the eggshell, measured by vernier caliper.

2.3.2 The algorithm for characteristic parameters

As practice shows, if an egg may be considered as a solid of revolution about the longitudinal axis, it is possible to consider the contour of the cross

section to be circular. Fig.2 was the profile of an egg, L is the longitudinal axis, O is the peak, Line MN is perpendicular to longitudinal axis, z is the perpendicular distance from the cross section to the peak of the profile, M is the left intersection with the profile, and N is the right, $\theta(z)$ is the angel between long axis and the tangent at point M . Fig.3 is the cross section at the position of Line MN , $A(z)$ is the area and $C(z)$ is the circumference length.

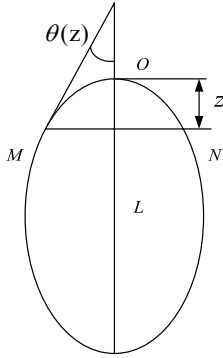


Fig.2 The profile of egg

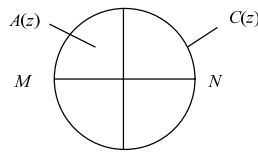


Fig.3 MN cross section

Hence, from the perspective of the differential calculus and integral calculus, the volume V and surface area S of the solid of revolution about the long axis can be found from the equations

$$V = \int_L A(z) dz \tag{6}$$

and

$$S = \int_{s'} C(z) ds \tag{7}$$

Where s' is the left contour of the egg's half-projection, ds is the differential operator along s' , with the following relation to dz .

$$ds = \frac{dz}{\cos \theta(z)} \tag{8}$$

Thus, equation (7) can be rewritten as

$$S = \int_L \frac{C(z)}{\cos \theta(z)} dz \tag{9}$$

Egg edge found out from the image was similar to the profile shown in Fig.2. Considering the discrete edge information, Volume in pixels (V_p) and Surface in pixels (S_p) are defined as followings:

$$V_p = \sum_{i=0}^L A(z_i) \tag{10}$$

and

$$S_p = \sum_{i=0}^L \frac{C(z_i)}{\cos \theta(z_i)} \tag{11}$$

Where L (unit: p_{ix}) is long axis in the image, $A(z_i) = \pi d^2(z_i)/4$, $d(z_i)$ (unit: p_{ix}) is the diameter of the cross section which has a distance of z_i to the peak of the edge in the image, $C(z_i)$ is the corresponding circumference length, $\theta(z_i)$ has the similar meaning to the above $\theta(z)$, which can also be calculated from the edge information.

3. RESULTS AND DISCUSSION

The results of the measurements and calculations are shown in Fig.4 and Fig.5. Fig.4 is the scattergram of samples about the V and V_p , from which we can see that the volume(V) seems to increase linearly accompanying with the increasing of V_p . Hence, with SAS V9.0, we can easily find the model to predict egg volume:

$$V = 3.447E - 05 \times V_p + 23.296991 \tag{12}$$

with $R = 0.88$. The proportion of samples with statistical errors in domain of $\pm 1cm^3$ reaches 52%, and 89% in $\pm 2cm^3$.

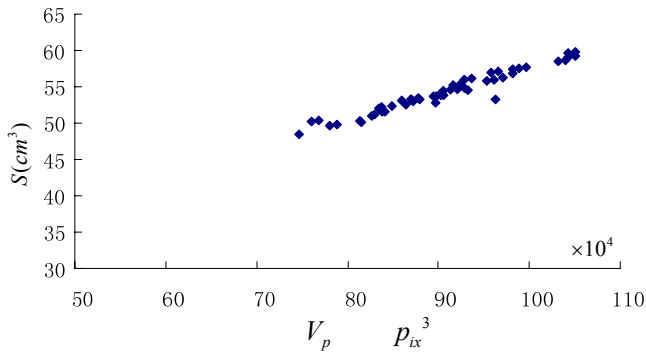


Fig.4 Scattergram of samples about V and V_p

And Fig.5 is the scattergram of samples about S_p and S , from which we can see that the surface area(S) tends to become large as long as the increasing of S_p linearly. Thus, we can easily get the model for surface area:

$$S = 5.985E - 04 \times S_p + 44.684279 \quad (13)$$

with $R = 0.86$. The proportion of samples with statistical errors in domain of $\pm 1cm^2$ reaches 49%, and 87% in $\pm 2cm^2$.

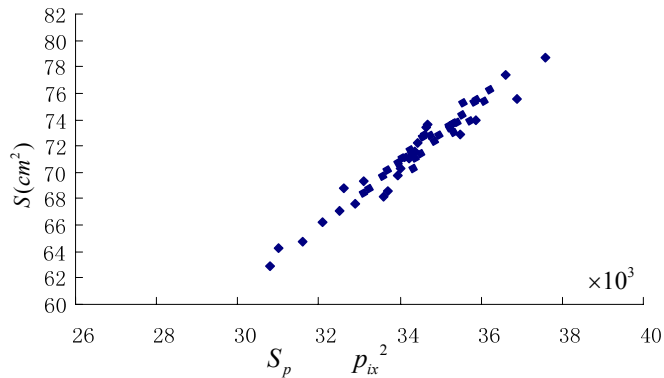


Fig.5 Scattergram of samples about S and S_p

There are may several factors working on the models' precision: (1) the projection of egg's longitudinal axis in the image may not be strictly vertical,(2) the machine vision system may have dimension distortion. However, the results show that machine vision technology can also be used to predict volume and surface area instead of traditional models in practice. Besides, the new method can improve the calculation efficiency, which will be welcome in poultry industry and biological studies. Furthermore, the linear models can be explained much better in geometrics.

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