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Indirect Method for Egg Weight Measurement Using Image Processing

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***Abstract*— An algorithm for indirect egg weight volume measurement using image processing is proposed. Regression analysis is used for approximation of relationship between egg weight and egg geometric parameters – perimeter, area, major and minor axis, shape coefficients and volume. The values of volume for each egg sample collected by image processing and traditional method based on water displacement were compared using percent differences between data. The experimental results show that the most significant parameters are egg area and volume with the following approximation - polynomial with order 3 with a value of R^2=0,9439 and exponential regression with R^2= 0,9235.**

***Keywords*—egg weight, image processing, regression analysis, geometric parameters, shape coefficients.**

I. Introduction

Main requirement in egg grading systems is weight eggs classification which is specified as per-egg weight ranges as shown in Table 1 [8]:

TABLE 1
EGG WEIGHT RANGES

	Egg Size	Egg weight
1	XL-very large	73 g
2	L-large	63 g to 73 g
3	M-medium	53 g to 63 g
4	S-small	under 53 g

An analysis of literature for existing grading systems have shown that there are many automatic system for egg grading which are used mainly for defect detection [3,6] and for detecting internal blood spots and eggshell dirt [2,5]. Different methods such as optical, mechanical, spectral have also been used for classification of eggs using different classification criterion. In [7] near infrared spectroscopy is used for detection of blood spots in eggs. A developed computer vision algorithm [4] is used for dirt egg detection and determination of defected eggs size. Black and white images are used for egg defect detection [1].

The objective of the study is to propose an algorithm for indirect measurement of egg weight using machine vision system and image analysis.

II. Materials And Methods

The indirect method for egg volume measurement includes the following main steps: egg image acquisition using appropriate machine vision system, image analysis using appropriate image procedures for calculation of egg geometric parameters and statistical methods for determining the relationship between the weight of the eggs and their geometric parameters.

A. Machine Vision System

The components of machine vision system for egg grading shown on Fig. 1. include:

- CCD camera VIDO AU CC540HDN - 1
- Light source system – 2
- Personal computer – 3
- Work surface – 4.

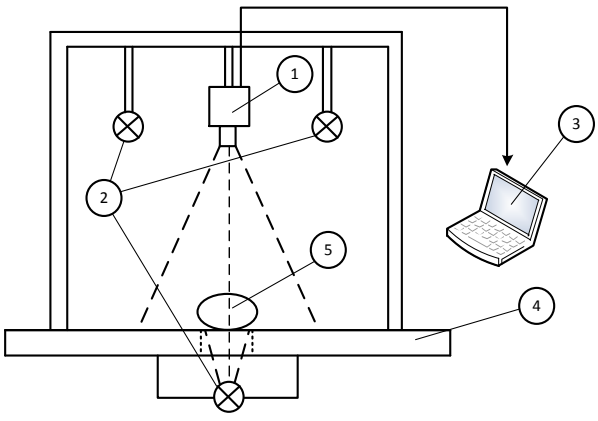

Fig. 1. Machine vision system for egg grading

The technical data of the color CCD video camera used are the following:

- Photo sensor - 1/3 "SONY Super HAD matrix with a resolution of 795 x 596 pixels;

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- Resolution - 540 TVL;
- Video output - composite video with BNC connector;
- Electronic shutter - from 1/50 - 1/120000 sec;
- Spectral sensitivity - visible and infrared range (800 ÷ 1200 nm).

The system provides illumination of the object in two different directions - over, to analyze the color characteristics and bottom, with the aim of radiographic object. LED lighting with white light and a color temperature of 3000K is used.

B. Image Processing Algorithm

The proposed algorithm for egg image processing includes following main steps: RGB image acquisition (1), converting RGB to Gray image (2), converting Gray to Black/White image (3) and calculation of geometric egg parameters (4). The block diagram of the proposed method is shown in Fig 2.

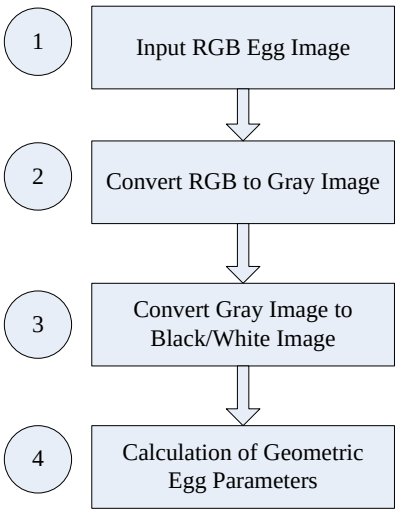

Fig. 2. Block diagram of the proposed method

One of the main procedures for working with visual system is calibration procedure. Determined numbers of pixels correspond to the diameter of the object in horizontal and vertical direction. Identifying two coefficients Kx and Ky (mm/pix), provide millimeters corresponding to one pixel in X and Y direction:

$$K_x = \frac{D}{P_x},\ K_y = \frac{D}{P_y}, \qquad (1)$$

Where D, mm is the diameter of the standard circular object;

Px, Py - the number of pixels in the directions X and Y, corresponding to this diameter.

The coefficients K_X and K_Y can be used to measure distances in a visual image, when the desired result should be in millimeters. For example, the distance between point A (X_A,Y_A) and B (X_B, Y_B) is obtained based on the Euclidean distance of the equation as follows:

$$D_{AB} = \sqrt{\left[(X_A - X_B)\cdot K_X\right]^2 + \left[(Y_A - Y_B)\cdot K_Y\right]^2}\ \text{, mm.} \quad (2)$$

For converting the images in gray and then in black/white (binary) image are used functions in MATLAB. After receiving the gray image it is converted into a binary with two types of pixels - white (object pixels) and black (background pixels). This is done by standard procedure using threshold gray image segmentation.

The calculated geometric egg parameters using images of the eggs are minor and major axis, area, perimeter and two shape coefficients.

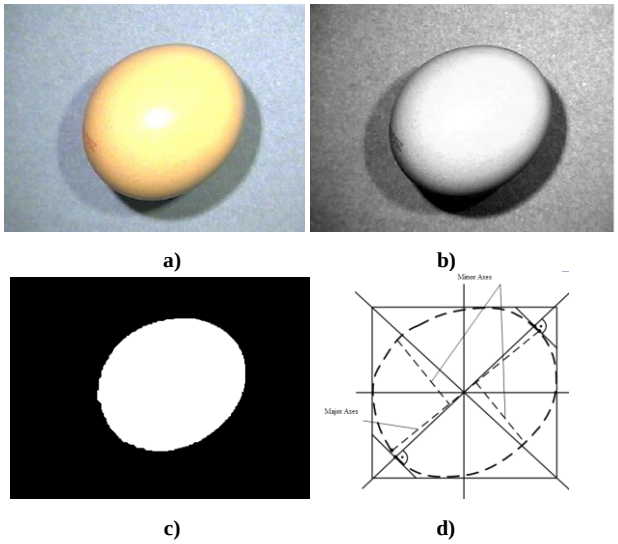

Fig. 3. Main steps of image processing algorithm

a) input RGB egg image, b) gray egg image, c) binary image, d) geometric parameters calculation

The geometric egg parameters are obtained as results of Matlab function *regionprops*.

Other three parameters are also calculated – two coefficients of egg shape (K_1 and K_2) and egg volume.

$$K_1 = \frac{P^2}{S} \quad \text{and} \quad K_2 = \frac{A}{B}, \qquad (3)$$

Where P is egg perimeter;

S – egg area;

A - minor axis;

B – major axis.

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The egg volume is calculated using the following equation:

$$V_c = \frac{2\pi}{3} AB, \quad \text{cm}^3 \qquad (4)$$

Where A is the minor axis;

B – major axis.

C. Indirect Method for Weight Egg Measurement

The results are analyzed to determine the relationship between the weight of the eggs and their geometric parameters.

Tools used for this purpose is regression analysis of the eggs weight and their geometric parameters. For this approximation a set of analytical models is performed and for each of them the coefficient of determination R^2 is calculated.

III. Results And Discussion

Results for calculated geometric parameters of eggs are shown in Table 2. The second column is egg weight which is measurement using precise electronic scale.

TABLE 2
EGG WEIGHT RANGES

Egg number	Weight, g	Perimeter, cm	Area, cm^2	Major axis, cm	Minor axis, cm	K_1	K_2	V_c, cm^3	V_{WD}, cm^3	Percent differences
1	54,43	15,512	18,51	5,23	4,47	13,00	0,85	48,89	45	7,96
2	52,36	15,567	18,38	5,42	4,28	13,18	0,79	48,51	46	5,18
3	48,66	15,344	17,62	5,43	4,09	13,36	0,75	46,41	45	3,05
4	43,70	14,625	15,97	5,12	3,98	13,39	0,78	42,67	40	6,26
5	43,68	15,089	16,79	5,51	3,86	13,56	0,70	44,54	41	7,95
6	49,14	15,221	17,47	5,40	4,13	13,26	0,77	46,69	45	3,62
7	47,81	15,025	17,22	5,24	4,15	13,11	0,79	45,51	46	1,07
8	62,56	17,015	21,53	6,27	4,37	13,44	0,70	57,32	60	4,67
9	57,49	16,574	20,81	5,93	4,47	13,20	0,75	55,43	56	1,04
10	63,73	16,504	20,89	5,74	4,64	13,04	0,81	55,68	56	0,57
11	45,61	14,704	16,54	5,04	4,20	13,07	0,83	44,29	42	5,17
12	61,09	16,219	20,07	5,63	4,57	13,11	0,81	53,80	53	1,49
13	50,67	15,408	17,99	5,37	4,21	13,19	0,78	47,36	48	1,35
14	60,28	16,274	20,13	5,72	4,45	13,16	0,78	53,28	50	6,16
15	53,52	15,886	18,92	5,69	4,18	13,34	0,74	49,79	47	5,61
16	42,75	14,548	15,83	5,10	3,93	13,37	0,77	41,92	44	4,95
17	56,55	15,836	19,02	5,51	4,34	13,17	0,79	50,09	47	6,19
18	58,83	15,832	19,15	5,36	4,54	13,09	0,85	50,84	49	3,61
19	37,22	14,208	14,91	5,17	3,65	13,54	0,71	39,53	39	1,35
20	55,67	15,517	18,48	4,99	4,61	13,03	0,92	48,14	50	3,86
21	55,64	15,759	18,91	5,46	4,36	13,13	0,80	49,80	50	0,40
22	52,81	15,206	17,79	5,06	4,41	13,00	0,87	46,72	48	2,73
23	50,52	14,991	17,25	5,06	4,31	13,03	0,85	45,69	47	2,87
24	52,60	15,542	18,29	5,37	4,33	13,20	0,81	48,63	46	5,40
25	54,80	15,527	18,42	5,23	4,49	13,09	0,86	49,09	51	3,90
26	58,75	15,884	19,31	5,39	4,55	13,06	0,84	51,28	51	0,54

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Columns from third to seventh are calculated from egg images. The last column for egg volume is obtained using water displacement method for volume measurement as a reference method for assessment the accuracy of volume calculation using equation 4.

The values of volume for each egg sample collected by image processing and traditional method based on water displacement were compared. The percent difference between two data points was calculated as the ratio between the absolute value of the difference between the two values and the expected value:

$$Perecent \quad differences = \frac{|V_C - V_{WD}|}{V_C}.100,\% \qquad (5)$$

The results of approximation with analytical model and the values of R^2 are shown on Fig. 4, 5, 6, 7, 8, 9 and 10.

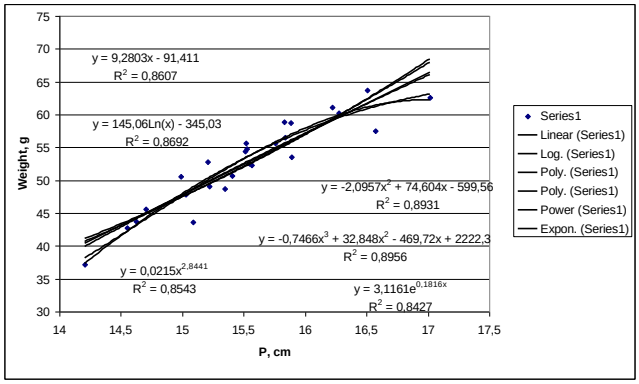

Fig. 4. Approximation of the weight from the perimeter

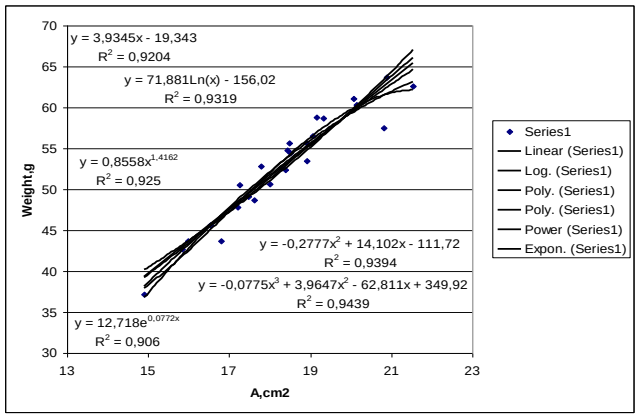

Fig. 5. Approximation of the weight from the area

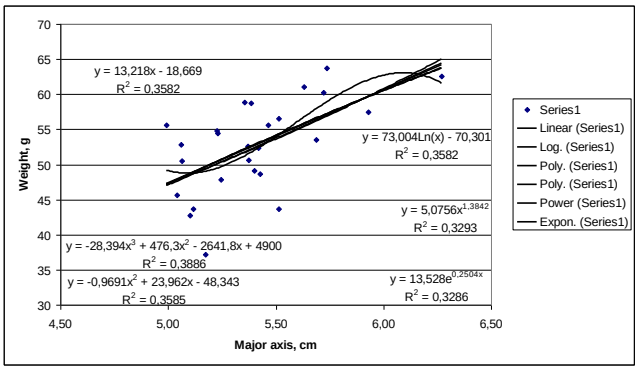

Fig. 6. Approximation of the weight from the major axis

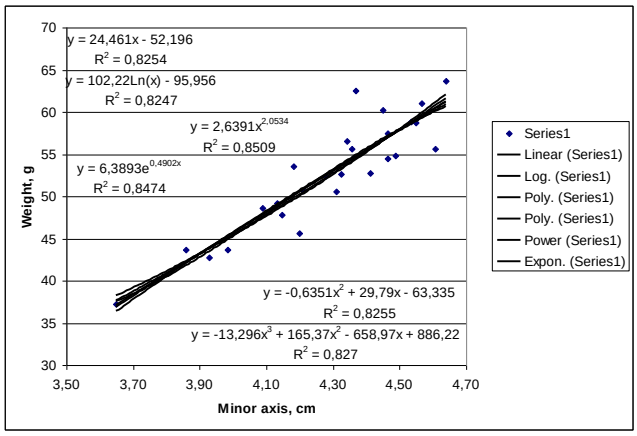

Fig. 7. Approximation of the weight from the minor axis

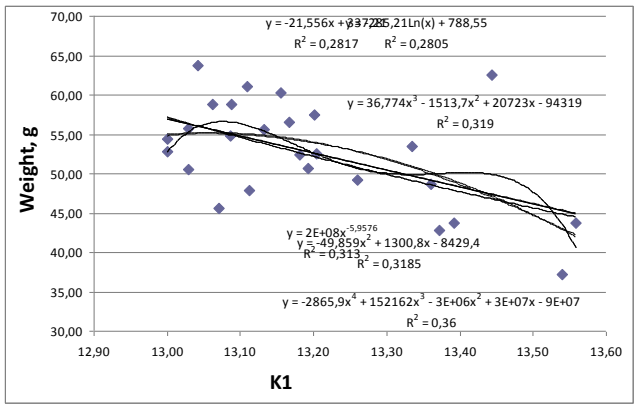

Fig. 8. Approximation of the weight from K_1

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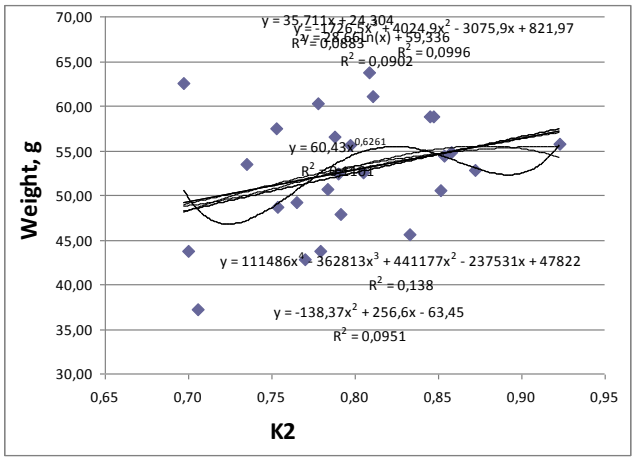

Fig. 9. Approximation of the weight from K_2

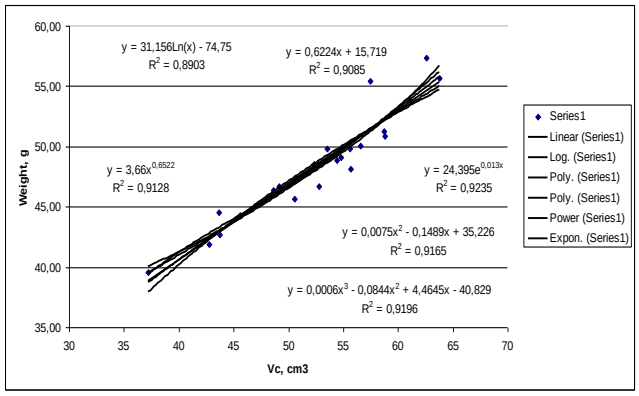

Fig. 10. Approximation of the weight from the volume

The results in Fig. 4 show that for the approximation of the dependence of weight on the perimeter, the good score were obtained by a polynomial of 4th order with a value of R^2 = 0,8965. The results in Fig. 5 show that for the approximation of the dependence of weight on the area, the good score were obtained by a polynomial with order 3 with a value of R^2 = 0,9439. The results in Fig. 6 show that the highest value of R^2 = 0,3886 were achieved using polynomial with order 3. The relationship between the weight of the eggs and their minor axis is approximated with regression of type Power (Fig. 7) with value of R^2 = 0,8509. The values of R^2 for shape coefficients K_1 and K_2 (Fig. 8 and Fig. 9) are insignificant and do not show relationship between them and egg weight.

The relationship between egg weight and volume (Fig. 10) is approximated using exponential regression with R^2 = 0,9235.

The percent differences between data for egg volume calculated from digital egg image and the values obtained using water displacement method are less than 10%. This result shows that image analysis is appropriate for calculation of egg volume with values near to the reference.

IV. Conclusion

An algorithm and procedure for indirect measurement of egg weight using egg digital images are developed and tested. The relationship between the egg weight and geometric parameters are approximated using regression analysis and coefficient of determination. The results show that perimeter, major and minor axes, shape coefficients K_1 and K_2 are insignificant for indirect measurement of egg weight using image analysis. Most significant parameters are area and egg volume with the following approximation - polynomial with order 3 with a value of R^2 = 0,9439 and exponential regression with R^2 = 0,9235.

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