Duck Egg Sexing by Eccentricity Determination Using Image Processing

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***Abstract*—Manual duck egg sexing is practiced in the Philippines for a long time now. The method used was established on the proposition that the male duck eggs are elongated while the female eggs are more rounded. This paper proposes for the use of eccentricity to measure the roundedness of the egg. It aims to establish the accuracy of egg eccentricity in determining the sex of fertilised duck eggs. A total of 103 egg samples are considered in this study. A two-dimensional still picture of each egg sample is taken and enhanced before the eccentricity is determined. The eccentricity of each egg is computed using Matlab, a numerical computing software. After determining the eccentricity of each egg sample, a specific eccentricity threshold value is determined to separate the male from the female. Any egg sample which eccentricity is falling below this threshold value is considered a female egg, while any egg with eccentricity value equal to or higher than the threshold value is a male egg. The accuracy of the proposed method is based on the actual sexing done on the hatched eggs using the vent sexing method. Results show that with an eccentricity threshold value of 0.6441, up to 86% accuracy is attained in predicting the sex of duck eggs using the proposed method. This accuracy has a high significance in the segregation of female and male eggs in the duck egg industry in the Philippines and other parts of Southeast Asia.**

***Index Terms*—Duck Egg Sexing; Eccentricity; Egg Shape Sexing; Egg Image Processing.**

I. INTRODUCTION

In 2002, the duck egg industry in the Philippines generated about US$806 million [1]. It is a significant industry in the country that produces several products. Products like balut, salted eggs and penoy are the more popular. The balut is a common delicacy in the Philippines and other parts of Southeast Asia but considered to be a taboo food in the western world. It is made from a fertile and preferably male egg incubated for 14 days before it is boiled and eaten. The salted egg is typically an infertile egg, soaked in a brine solution also for several days. The penoy is an infertile egg and incubated for several days before it is boiled and served.

Some processes are involved inherent to these duck egg products. One process involves the sorting out of fertile from the infertile eggs. Infertile eggs usually end up as penoy and salted eggs. Fertile eggs, on the other hand, are further sorted to separate the male from the female ones. This is where egg sexing comes in. Male eggs are hatched for about two weeks to become balut. Female eggs are incubated until completely hatched, and later developed to become duck layers.

II. EGG SEXING METHODS

In the past, studies were conducted on egg sexing using different methods and sex markers. Studies done on avian eggs in general [2], [3] assert that the detection or control of egg sex remains unknown. However, these studies contemplated that the egg size difference between male and female eggs might be a possible egg sex marker. Further, in an egg sexing study on chicken eggs using the morphometric method [4], it was found that the egg width-to-egg length ratio is related to the sex of the hatched chicks. According to this study, eggs with higher ratios have a higher probability of becoming female chicks. A comprehensive discussion on some egg sex markers to eventually identify the sex of an egg are presented in [5]. Egg sex markers that were discussed include some physiological parameters like a heartbeat [6] and [7], specific chromosomes in the egg [8], sex-specific compounds present in the blood and embryonic fluid [9]. However, the discussion on egg sexing proposed in the above-described papers used chick embryos, particularly gallus. Further, the sex markers described above involve individual instruments, sensors and processes to determine the definite difference between male and female eggs eventually.

In the Philippines, duck egg sexing is an essential process in the duck egg industry. As of this writing, duck egg sexing in the Philippines is done manually by experienced duck egg sorters and is based on the premise that male eggs are more elongated than female eggs. However, in an undergraduate thesis [10], manual duck egg sorters who were utilised in the study did not have high precisions in duck egg sorting. Three sorters with different years of experience managed to have accuracies ranging from just about 43% to 77% in duck egg sexing.

Figure 1(a) shows an elongated egg, and Figure 1(b) shows a more rounded egg. Figure 1(a) is identified as egg number 50 in this study, and a male duckling came out from it after incubation. The egg in Figure 1(b) is egg number 62 in this study, and after incubation, a female duckling came out. By inspection, the male egg is more drawn-out than the female counterpart. In an actual situation, not all male eggs have this more apparent drawn-out shape compared to the female egg, or the roundedness of the female egg compared to the male egg. This paper quantifies the degree of roundedness of an egg to qualify it to be a female egg or a male egg. In Geometry, one way of measuring the roundedness of an object is the eccentricity of that object. This study aims to establish the accuracy of the duck egg eccentricity-determination method in identifying the sex of fertilised duck eggs.

(a) Male Duck Egg

(b) Female Duck Egg

Figure 1: A relatively more elongated (a) male egg and more rounded (b) female duck egg

The eccentricity of an elliptic object is the ratio of the distance between the foci to the length of the major axis, or this is the same thing as the ratio of the distance between the centre of the ellipse and each focus to the length of the semi-major axis. From this definition, as the eccentricity of an elliptic object approaches zero, the object approximates a circle. On the other hand, as the eccentricity approaches a value of 1, the object approximates a straight line. Since eggs are more likely to resemble an ellipse, the researcher opted to use the eccentricity of the egg shape (treated as an ellipse) to determine the sex of a duck egg. In Figure 1, the male egg is more elongated than the female egg. The male egg, therefore, has an eccentricity that is greater than the eccentricity of the more rounded female egg. Following the premise that male eggs have higher eccentricity than female eggs, this study specifically aims to determine the specific eccentricity value that identifies a male egg from a female egg or vice versa. This specific eccentricity value, referred to as the eccentricity threshold value in this paper will be used for possible automation of male-female egg sorting. The automation of egg gender sorting eliminates the present manual sorting method which is very labour intensive, apart from produces unreliable sorting results.

III. METHODOLOGY

This study involves the following processes to determine the eccentricity threshold value: 1. Acquisition of duck egg samples, 2. Egg identification by giving a number to and marking each egg sample, 3. Still picture taking to capture a two-dimensional image of an egg sample, 4. Image processing to enhance and to produce the egg region in grayscale to determine the eccentricity and 5. Incubation and sexing of ducklings to identify the actual sex of each egg sample.

The fertilised duck egg samples are taken from a commercial duck egg product producer in Pateros, Metro Manila, Philippines. Pateros is known to be the home of significant duck egg product producers and is regarded as the balut capital of the Philippines. The egg samples come from different duck egg producers in the locality collected by a major duck product manufacturer. The total number of egg samples is 170 randomly picked irrespective of egg shape and size, from a pool of fertilised eggs. The egg samples in this paper are higher than the egg samples considered in the prior paper [11] which is only 120. The increase in the number of egg samples is to improve the accuracy of the method being proposed. The collected eggs are incubated in three different incubation periods. The eggs are numbered from 1 to 170 for identification purposes. After marking the unique number of each egg sample, a still picture of each egg is taken. This still picture is processed until a pronounced image of the egg section is achieved. The egg section is used to determine the eccentricity of each egg sample.

After a still picture of each egg is taken, the eggs are then incubated until hatched. The still images of the eggs are processed before the eccentricity value is calculated. Image processing and image property calculation are done using the image processing toolbox of Matlab R2011. The more challenging part of image processing in this study is the duck egg edge detection to produce the egg shape and egg region. The objective is to convert each captured image in grayscale with the egg region in white with a black background. In this way, the calculation of the properties, e.g. eccentricity, of the whole captured image involve only the egg region. Before this and with the use of Matlab software, the egg image needs to be enhanced: conversion to grey (im2bw, mat2gray), contrast adjustments (imadjust), thresholding (im2bw). Additionally, the edge detection can be made easier by placing each relatively white textured egg sample on a darker background while the egg image is captured [10]. In this way, image enhancing is easier. The process of duck sexing using image processing by eccentricity determination as described above is illustrated in Figure 2.

For automation of egg sexing, Matlab is more appropriate to be used to allow the computers to be interfaced with microcontrollers. The microcontrollers are used to move the eggs through conveyors automatically, actuate cameras to capture the egg image, do image processing and eventually determine the sex through some sex markers, like egg shape eccentricity.

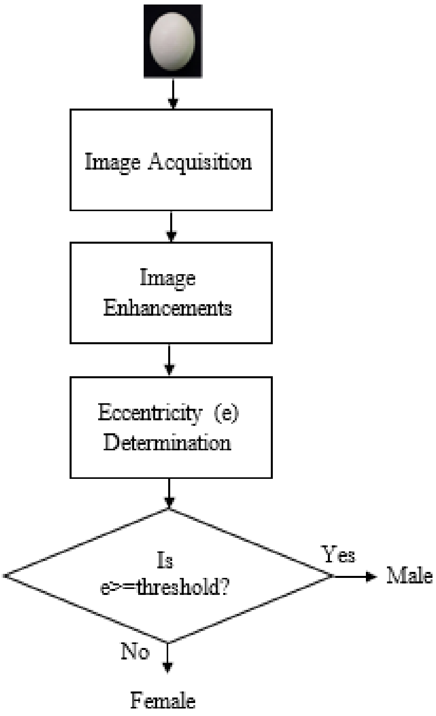


Figure 2: Process flow of duck sexing using image processing by eccentricity determination.

The processed image of the duck eggs in Figure 1 is shown in Figure 3. Figure 3(a) is the same as Figure 1(a) in greyscale, while Figure 3(b) is the monochrome version of Figure 1(b). Figure 3 shows the detected edges of the eggs in Figure 1 and converted the whole egg region into all white. Figure 4 illustrates the egg samples with the egg region in white on a black backdrop. The conversion of the background into all black is done through the implementation of thresholding in Matlab.

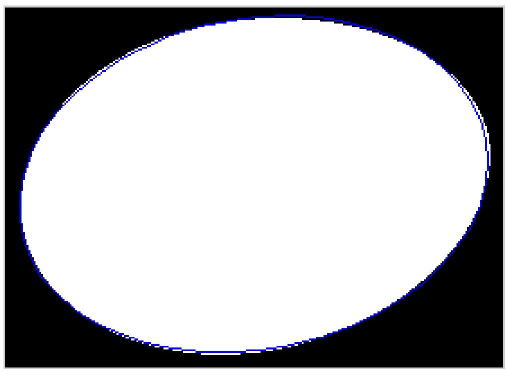
(a) Male duck egg

(b) Female duck egg

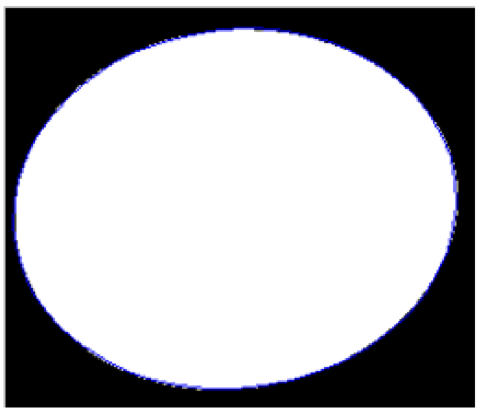
Figure 3: The equivalent grey scale illustration of the (a) male and (b) female egg regions of the ones illustrated in the previous figure.

After determining the egg edges and converting the whole egg region to white on a black background, the eccentricity of the detected shape is determined. The eccentricity of each egg sample is computed using the 'regionprops' function of Matlab. 'regionprops' calculates the eccentricity of an object or region by solving an ellipse with the same second moments as the shape or region. The object, in this case, is the egg's shape converted to full white. 'regionprops' first calculates the co-variance matrix of the region. Resolution into a canonical form of the resulting matrix then follows where it is represented by eigenvalues and eigenvectors. The eigenvalues are the major and minor axis lengths, while the eigenvector is the orientation of the axes. Co-variance matrix calculation is the same as fitting a multivariate normal distribution. The shape, therefore, of the multivariate distribution is determined by the covariance matrix. Ellipses are produced in the normal distribution.

To demonstrate the resulting ellipse as determined by 'regionprops' when eccentricity is calculated, the researcher adopted a Matlab code that displays the resulting ellipse over the grey scale image of the egg. Figure 4 shows the resulting ellipse (blue colour) having the same second moments as the egg's edges in grey scale image of the male and female eggs illustrated in Figure 3. As shown in Figure 4, the calculated ellipse closely bears a resemblance to the shape of the duck egg region, with a slight difference. Referring again to the egg regions in Figure 4, the eccentricity value calculated by 'regionprops' is 0.7154 for the male egg and 0.5927 for the female egg. The orientation of the male and female eggs in Figure 4 are calculated as 10.7886^{0} and 7.1410^{0}, respectively.



(a) Male duck egg



(b) Female duck egg

Figure 4: The resulting ellipse (blue line) having the same second moments as the (a) male and (b) female egg regions as determined by 'regionprops'

After the incubation periods, 103 eggs hatched out of the 170 egg samples considered. Some eggs did not hatch while others hatched, but the ducklings eventually died just after coming out from the shell. All live ducklings underwent the anal vent sexing method, moments after hatching. Sex identification of the hatched ducklings using the vent method allows the determination of the actual sex of each egg sample. The results are used as the basis for determining the accuracy of the proposed duck egg sexing method by eccentricity. Experienced personnel administered the sexing of the day-old ducklings. The vent sexing method is very accurate in determining the sex of a duckling, especially when appropriately administered.

IV. DATA AND DISCUSSION OF RESULTS

The use of the vent sexing method on the hatched ducklings resulted in the identification of 55 males and 48 females for a total of 103 ducklings. Table 1 shows the calculated eccentricity of the hatched eggs with the corresponding identification number. The eggs are identified to be male and female by the vent sexing method, which was administered moments after the eggs are hatched. The eccentricity values for female hatched eggs range from 0.5922 to 0.6910. The average eccentricity for female hatched eggs is 0.640598. On the other hand, the calculated average eccentricity values for the male hatched eggs in this batch is 0.676407 with values ranging from 0.6188 to 0.7411. On the average, female eggs have eccentricity values that are relatively lower than the eccentricity values of their male counterpart by about 5.59%.

Inspecting the values of the eccentricity in Table 1, an eccentricity threshold value of 0.6441 will give the highest accuracy in predicting the sex of a fertile duck egg. That is, any egg with an eccentricity equal to or higher than 0.6441 is a male egg, while eggs with eccentricity value lower than 0.6441is a female egg. The overall accuracy in predicting the sex of duck eggs using the proposed method is 86.408% (89 out of 103) with the threshold value of 0.6441. For male eggs alone, the accuracy is 94.545% (52 out of 55). However, the accuracy in predicting the sex of female eggs is lower at 77.083% (37 out of 48). It is interesting to note that the proposed method has a higher accuracy in predicting the sex of male eggs than in predicting the sex of female eggs.

In the actual fertilised egg segregation in the Philippine scenario, the higher inaccuracy of the proposed method in female sex prediction is still useful in the sense that the female eggs classified as male as a result of this inaccuracy will end up as balut. On the other hand, the male eggs that are erroneously classified by the proposed method as female to become future layers are still useful. They become ganders (male ducks) for egg layers to produce fertilised eggs. A ratio of 1:15 (1 gander is to 15 layers) up to 1:25 is common in the duck raising industry in the Philippines.

Table 1
The Eccentricity of the Male and Female Hatched Eggs

Female		Male	
Egg ID No.	Eccentricity	Egg ID No.	Eccentricity
1	0.6431	2	0.6809
21	0.6685	3	0.6622
25	0.6369	4	0.6470
32	0.6314	5	0.6838
33	0.6501	7	0.6839
36	0.6473	11	0.7091
37	0.6236	12	0.7039
38	0.6264	14	0.6704
39	0.6752	15	0.7047
43	0.6910	17	0.6742
52	0.6665	18	0.6784
53	0.6277	19	0.6902
55	0.6546	22	0.6738
61	0.6655	23	0.7003
62	0.5927	24	0.6452
64	0.6265	26	0.7067
65	0.6248	27	0.6516
67	0.6239	28	0.6746
68	0.6640	29	0.6459
69	0.6102	31	0.6702
70	0.6689	34	0.6578
72	0.6019	48	0.6441
75	0.6394	50	0.7154
76	0.6300	56	0.7116
77	0.6580	57	0.6445
80	0.6685	59	0.6794
85	0.6440	60	0.6452
90	0.6260	71	0.6535
92	0.6221	73	0.6283
93	0.6165	78	0.6841
95	0.6189	82	0.7282
96	0.5722	83	0.6662
98	0.6281	84	0.7006
101	0.6361	86	0.6729
103	0.6502	87	0.6849
118	0.6038	91	0.6546
123	0.6860	94	0.6611
124	0.6605	97	0.669
137	0.6853	105	0.6491
145	0.6702	107	0.6333
146	0.6459	108	0.6188
150	0.6638	111	0.6457
152	0.6413	112	0.6670
156	0.6222	115	0.6636
157	0.6844	117	0.6858
161	0.6383	120	0.6526
162	0.6022	127	0.6889
168	0.6141	128	0.7411
		134	0.7206
		136	0.7266
		139	0.6871
		144	0.6794
		147	0.6811
		165	0.7195
		169	0.6838

V. CONCLUSION

The results show that the proposed eccentricity determination method of duck egg sexing has an accuracy of more than 86% with 0.6441 as the eccentricity threshold value. This accuracy is significant in the segregation of male and female eggs for specific duck egg products and purposes in the duck egg industry in the Philippines. Manually, the more than 5% average difference between the eccentricities of male and female eggs is small, and the difference might not be very obvious. However, when machines are used to compare the eccentricity values, the 5% average difference is enough to segregate male eggs from female eggs. Therefore, the computed eccentricity of a duck egg qualifies as a sex-specific marker for future automation of duck egg sorting in the Philippines. In using this method, however, care must be observed in taking still pictures of the egg samples prior to eccentricity determination. The camera view must be perpendicular to the plane of the eggs' length and width. The eggs must not be tilted toward the camera to avoid significant inaccuracies in the calculated eccentricity. Also, a further study on the topic is recommended with the use of 3D pictures to study the egg structure in more detail and to avoid inaccuracies related to the above-mentioned egg-camera orientation problem.

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