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Original

# A new application of morphometric variables and image processing to determine day-old chicken sex

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**Abstract:** One of the principal activities in the poultry industry is determine the sex of chickens of one day old, in this manner, the poultry sector could decide if the chick would be destinated to meat or egg production sector. Currently, the principal method to estimate sex in day-old chickens is performed manually by an expert. In this paper, we present a non-invasive technique to determine the sex of day-old chickens based on image processing algorithms. The technique analyzes morphometrical attributes from chicken using the slow and rapid growth of primary and secondary feathers patterns and linear discriminant analysis models. Based on the area formed with the superior points of each feather, the technique is capable to determine the sex of day-old chickens with an accuracy of 94.4%, providing a cheap, non-invasive, and high accurate technique that could be implemented onto a dedicated and automated system.

*Keywords:* non-invasive sexing, UV vision technique, poultry system, discriminant analysis, in-situ sexing grade

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## 1. Introduction

Poultry has become the fastest-growing sector within the animal-origin food production industry (Stadig et al., 2016). The two principal branches in this sector are egg and meat production, both with specific activities to increase productivity. One of these activities is sexing chicks of one day old, to separate into the required branch (Otsuka et al., 2016).

Nowadays, there are several sexing methods with different approaches: based on feather pattern of day-old chickens using digital image processing (Tao et al., 2004); cloacal observation with an endoscope system (Otsuka et al., 2016); embryo pattern analysis using hyperspectral vision system (Göhler et al., 2017); and using near-infrared (NIR) Raman and fluorescence spectroscopy (Galli et al., 2018). Despite some of the systems reported until now, the development of an automatic chick separation method remains as expensive because of the use of highly specialized equipment and the intervention of specialized personnel. Perceiving the daily advance update, the trends are the development of cheap, accurate, non-invasive systems, and inside political regulatory requirements. The aim of this work is to describe the application of a technique to determine the sex of day-old chicken, based on linear discriminant analysis models, image processing, and morphometric feather growth patterns, presenting a cheap, non-invasive, and high accurate technique that could be easy to implement as an online system and into regulatory. Within an automatic and low-cost system, the sexing activities could be performed automatically without highly specialized personnel. This would reduce costs, there would be more automatic systems available to population and we would increase the yields for small and medium-sized companies that are dedicated to the poultry sector.

## 2. Materials and methods

### *2.1. Animals*

A sample of 28 Rhode Island Red chickens of day-old were used to develop the processing algorithm and the mathematical models. The sample size was calculated with a security level of 95%. The chickens were obtained from a commercial hatchery and the sex of chickens was known a priori. To validate, 300 day-old chickens from the same hatchery was used. The handling and care were according to SAGARPA NOM-062-ZOO-1999 and NOM-051-ZOO-1995 official regulations in Mexico. The real sex of the chickens was determined by an expert based on manual inspection of the feather.

### *2.2. Image acquiring System*

In order to acquire digital images, we developed a machine vision system based on ultraviolet (UV) light that is shown in Figure 1. The system is composed of a cabin to hold four light emission diode (LED) lamps with a wavelength of 365 nm. From the center-top of the cabin and fixed to 30 cm from the chicken, an ARTCAM-407UV-WOM ultraviolet USB2.0 CCD (Artray Co., Japan) camera is attached to detect the spectrum near-ultraviolet with sensitivity from 200 nm to 1000 nm and compose a digital image of 1360 x 1024 pixels. The camera system is equipped with an LM12JC1MS (Kowa Co., Japan) optical lens with a BP365-30.5 (MIDOPT, Inc. USA) near UV bandpass optical filter centered in 365 nm, to dismiss the rest of the wavelengths. Inside the cabin, we developed a special container device to hold the chicken feathers properly, without hurting the animal. The material used to manufacture the container was polylactic acid (PLA) shaped in such a way that the bird can rest inside while keeping its wings extended naturally. With this container, we assure that the wings remain open throughout the examination.

The image acquiring system is completed with a portable computer where all is controlled and where the algorithms and mathematical models to determine the sex of the chicken are computed.

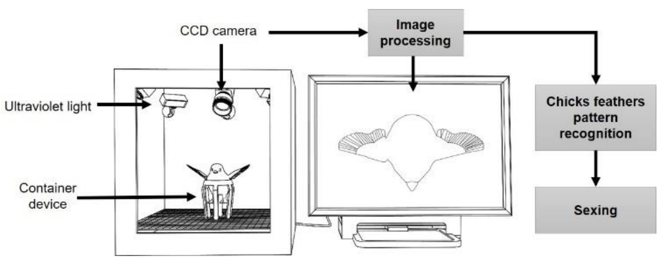


Figure 1. Experimental setup of the machine vision system based on UV light and feathers patterns.

### *2.3. Image processing algorithm*

Once the image is acquired, it was processed in MATLAB (The MathWorks, Inc., USA) to obtain the pattern of wing feathers. First, with the captured image through the UV camera, a thresholding method is performed in order to segment the image and acquire relevant information (Liu et al., 2015). In this case, the primary and secondary wing feathers of day-old chickens. The algorithm used for the automatic thresholding of the image was Otsu (Otsu, 1979), since it can achieve satisfactorily the segmentation of an image (primary and secondary) with a bimodal distribution histogram (Yuan et al., 2015). With the binary image obtained by the thresholding operation, we proceeded to the extraction of the skeleton (Bao et al., 2009) formed by the chicken wing feathers. To obtain the image of the primary and secondary feathers represented by a one-pixel wide line, the trimming process was used in order to remove any spurs or bridges that the previous step could produce. Finally, the features were extracted by pattern recognition of day-old chicks. Figure 2 shows the flowchart of image processing applied to chickens.

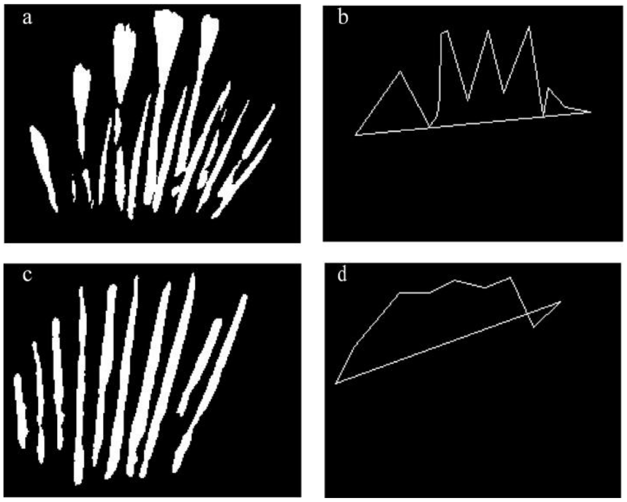


Figure 2. Image processing and area formed of female and male chickens. a segmented female feather. b Formed area with superior points of a female feather. c Segmented male feather. d Formed area with superior points of a male feather.

### *2.4. Data analysis*

For the selection process of male and female chicks, a database was created using the chick recognition pattern. Three variables were tested as predictors for the selection process: the total area in pixels ($A_p$) obtained from the recognition algorithm, the mean length in pixels of the wing feathers ($l_p$) of the chick is given by

$$l_p = \sum_{i=1}^{N} l_i / N \quad (1)$$

where $i$ is the feather, $l_i$ is the length of the feather and $N$ is the total number of feathers; and the deviation between the length of the primary and secondary feathers of the wings ($\sigma_f$) is calculated by

$$\sigma_f = \sqrt{1/_N \sum_{i=1}^{N} (l_i - l_p)^2} \quad (2)$$

The data set of the three variables for each group (male and female) were subjected to a Kolmogorov-Smirnov normality test with a level of significance of 5%. Through a linear discriminant analysis, mathematical models were composed for the selection process expressed by

$$F_F = u_{1F} + u_{2F} A_{pF} + u_{3F} l_{pF} \quad (3)$$

$$F_M = u_{1M} + u_{2M} A_{pM} + u_{3M} l_{pM} \quad (4)$$

where $F_F$ and $F_M$ are the discriminating functions for the female and male chicks respectively, considering $A_p$ and $\sigma_f$ as the predictive variables; $u_{1F}, u_{2F}, u_{3F}, u_{1M}, u_{2M}$ and $u_{3M}$ are constants.

## 3. Results and discussion

The sexing is done through the primary and secondary feathers of day-old chickens where the classification process is less expensive than the cloaca method and does not require skilled labor (Nandi et al., 2003). The pattern proposed for sexing considers the area formed by joining the maximum points of each feather and the maximum point of the first and last feather. As could be noticed, the feathers from female chicks have different lengths from primary and secondary feathers, and the parameter $l_p$ is expected to be significantly different from the male feathers. In Figure 2 it could be seen part of the image processing algorithm applied to a typical female and male feather. The segmented image and the area formed of female and male chickens are shown. It can be observed that the area formed by the female feather is greater than the formed by male feathers.

For the training set, different morphometric measurements (the total area in pixels, the deviation between the length of the primary and secondary feathers, and the mean length in pixels of the wing feathers) were tested to determine which of these are the best for sex selection. Figure 3a shows $l_p$ versus $\sigma_f$ and it could be seen that a conglomeration exists, nevertheless, there is no marked difference between them. The discriminant function obtained has 60.7% accuracy in sexing. According to Tao et al. (2004), this variable can be used for sex estimation; however, in this case, the difference between $\sigma_f$ in both males and female chickens is not representative in order to perform sexing accurately

Analyzing the $A_p$ versus $\sigma_f$ a separation of two data sets (Fig 3b) with an accuracy of 89.3% is obtained. On the other hand, in Figure 3c, it is observed how the separation of male from female chickens is evident in spite of the previous case. This test is obtained with the variables $A_p$ and $l_p$, where is significantly better with 96.4% in the classification process. In Table 1, we can observe a descriptive statistic of the three tested variables. The deviation between the lengths of the primary and the secondary feathers on female chickens is greater than males, the primary feathers of the females grow slower than secondary, in agreement to the experiment presented by Khosravinia and Manafi (2016). In male chickens, the growth is more uniform. We can observe that the mean length in pixels of the male feathers, the variation between data is greater than the presented in females; however, the difference between data is due to the fact that in the selected chicken sample there were male chickens with longer feathers than the female. Observing the total area of pixels formed by the process explained before, there is a marked difference between the pixel area formed by females than the area formed by males.

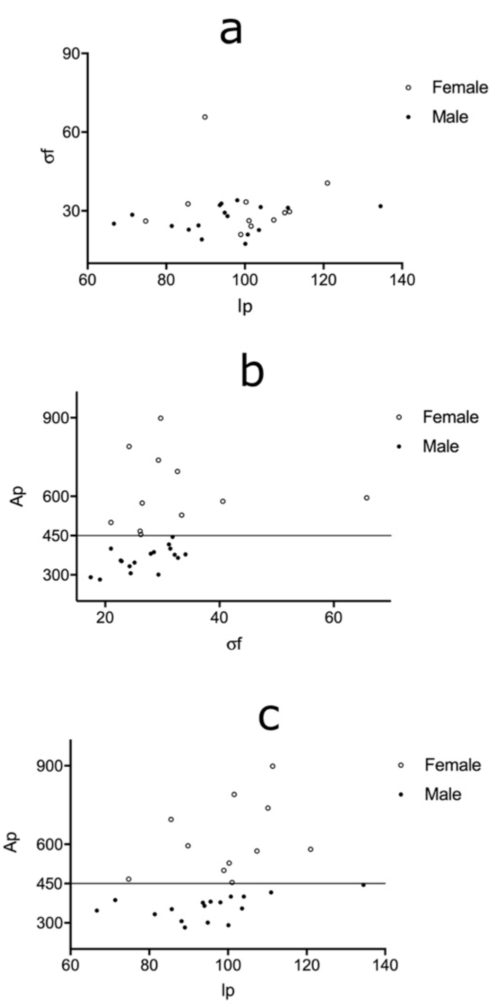


Figure 3. Dispersion charts of the training sets. a Dispersion chart with groups of the mean length in pixels of the wing feathers ($l_p$) versus the deviation between the length of the primary and secondary feathers ($\sigma_f$). b Dispersion chart with groups of the deviation between the length of the primary and secondary feathers ($\sigma_f$) versus the total area in pixels ($A_p$). c Dispersion chart with groups of the mean length in pixels of the wing feathers ($l_p$) and the total area in pixels ($A_p$).

In order to test the obtained model for sexing chickens, a random sample of 300 day-old chickens from a commercial hatcher was selected and inspected by the same expert as mentioned before. Only the variables $A_p$ and $l_p$ were considered. Figure 4 displays the conglomeration of data, which is very similar to the presented in Figure 3c. As can be seen, both the male and female chickens have a similar distribution along the axis of $l_p$, this can be interpreted as the mean length in pixels of the feathers, does not fluctuate significantly. However, $A_p$ is noticeably larger in the case of female chicks, and using this morphometrical variable, the sexing technique has an accuracy of 94.4%.

In Table 2 we can observe the descriptive statistics of the two mentioned variables. The standard deviation of the $l_p$ is similar in both male and female chickens, verifying the mentioned in the data presented in Figure 4.

Table 1. Descriptive statistics for model training.

| Variable | Sex | Mean (pixels) | Standard Deviation | Min (pixels) | Max (pixels) |
|---|---|---|---|---|---|
| $\sigma_f$ | Female | 32.31 | 12.28 | 21 | 66 |
| | Male | 26.83 | 5.12 | 17 | 34 |
| $l_p$ | Female | 100.17 | 12.96 | 75 | 121 |
| | Male | 94.86 | 15.32 | 67 | 135 |
| $A_p$ | Female | 619.91 | 142.78 | 454 | 898 |
| | Male | 359.76 | 45.82 | 282 | 445 |

$\sigma_f$ is the deviation between the lengths of the primary and secondary feathers of the wings
$l_p$ is the mean length in pixels of the wing feathers
$A_p$ is the total area in pixels

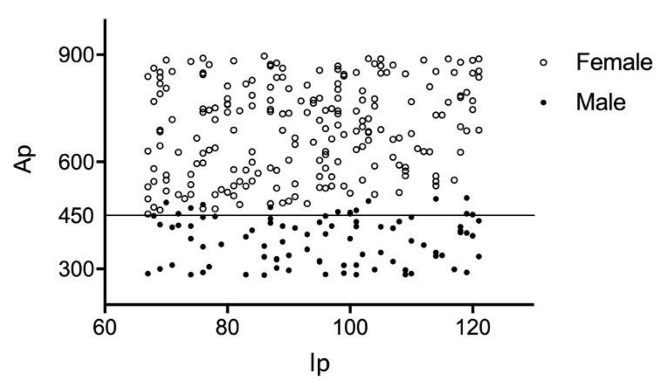


Figure 4. Dispersion chart with groups of the mean length in pixels of the wing feathers ($l_p$) and the total area in pixels (Ap) of the 300 one-day-old chickens

Table 2. Descriptive statistics of the validation model.

| Variable | Sex | Mean (pixels) | Standard Deviation | Min (pixels) | Max (pixels) |
|---|---|---|---|---|---|
| $l_p$ | Female | 92.27 | 15.5 | 67 | 121 |
| | Male | 94.68 | 15.68 | 67 | 121 |
| $A_p$ | Female | 695.01 | 128.23 | 454 | 896 |
| | Male | 382.82 | 66.2 | 121 | 283 |

## 4. Conclusions

The developed method and the described parts of the image acquiring system give us a cheap and easy to automate alternative compared to other techniques mentioned early in this paper. Based on image processing algorithms, a non-invasive system can be implemented in the poultry industry.

In order to implement the algorithm onto an automatic sexing system, technological development must be taken into count. Mechanical adjustments must be incorporated to hold the chickens automatically and sensory arrangements to spread light vision only when the chickens are correctly positioned.

With the data obtained and the technique developed, we can assure that using the morphometrical variables generated with total area in pixels ($A_p$) and the mean length in pixels of the wing feathers ($l_p$), we can perform chicken sexing with an accuracy of 94.4%. With this new method, the sex determination could be achieved around 1 second of image processing, in this way, an automatic day-old chicken sexing system can be developed, presented as a cheap, non-invasive, and high accurate alternative.

## Conflict of interest

The authors have no conflict of interest to declare.

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