K-means Segmentation Based-on Lab Color Space for Embryo Egg Detection

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Abstract. The hatching process also influences the success of hatching eggs beside the initial egg factor. So that the results have a large percentage of hatching, it is necessary to check the development of the embryo at the beginning of the hatching. This process aims to sort eggs that have embryos to remain hatched until the end. Maximum checking is done the first week in the hatching period. This study aims to detect the presence of embryos in eggs. Detection of the existence of embryos is processed using segmentation. Egg images are segmented using the K-means algorithm based on Lab color images. The results of the images acquisition are converted into Lab color space images. The results of Lab color space images are processed using K-means for each color. The K-means process uses cluster k=3, where this cluster divided the image into three parts, namely background, eggs, and yolk eggs. Yolk eggs are part of eggs that have embryonic characteristics. This study applies the concept of color in the initial segmentation and grayscale in the final stages. The results of the initial phase show that the image segmentation results using k-means clustering based on Lab color space provide a grouping of three parts. At the grayscale image processing stage, the results of color image segmentation are processed with grayscaling, image enhancement, and morphology. Thus, it seems clear that the yolk segmented shows the presence of egg embryos. Based on this process and results, K-means segmentation based on Lab color space can be used for the initial stages of the embryo detection process. The evaluation uses MSE and MSSIM, with values of 0.0486 and 0.9979; this can be used as a reference that the results obtained can indicate the detection of embryos in egg yolk.

1. Introduction
Hatching eggs is a way of development carried out in poultry farms. This process is very concerned about several factors, such as broodstock [1], egg condition (quality), and environment (temperature). Broodstock factors are genetic factors that can be determined by selecting the best broodstock. At the same time, the most important is the hatching process. The initial condition of the egg needs to be considered for its cleanliness [2], then when entering the hatching, it is necessary to regulate the temperature required. The eggs in the hatch are checked for embryonic development in the first week of hatching. This check aims to detect early embryonic eggs. If the egg does not have an embryo, it is removed from the incubator.

The process of hatching eggs is currently being developed with the application of technology [3]–[7], such as identification/classification of eggs, egg objects, sorting eggs before hatching, detection of embryos in the hatching process. In this study, we focus more on embryos detection in the egg image on hatching. Egg images are taken when the eggs have been hatched on the seventh day (one week in
hatching). It aims to detect the early embryo egg, if the embryo is not detected, the embryo development can be taken and can be used for consumption.

The process of detection of egg embryos uses the concept of image processing. The image acquisition is based on taking pictures of the egg candling process. The image processing process uses two concepts based on color [8] and grayscale. Color images contain three color components (red, green, and blue), and grayscale only has one color (gray). Color image processing is used to clarify the embryo detection process by converting it to grayscale.

Color image segmentation with the Lab can divide the area of objects according to the detected color uniformity. This segmentation process also applies the K-means clustering algorithm to separate areas that have similarities using distance calculation (Euclidean Distance). In this study, the next process is to clarify the egg embryo by grayscale image processing.

The concept implemented is based on improving image quality. Image enhancement is used to clarify the image so that when processed, giving better results. The results of this increase are used to detect objects by applying morphological operations. Morphological operations can provide a clear picture of an object by eliminating noise.

This article develops the concept of image segmentation based on the Lab color space. Besides, the results of segmentation Lab color image (initial) are processed by several methods, namely, grayscaling, image enhancement, and morphology. This article is divided into five parts. The first part explains the background, problems, and state-of-the-art of the research conducted. The second part describes the relevance and relation of the relationship between this study and previous studies to show the difference in embryo detection. The third part explains the research methods used. The fourth part describes the discussion and results of the experiments carried out. The last part is the fifth part is the conclusion part of the topic discussed in this study.

2. Related Works
In this section, we discuss the relevance and relationship of previous studies related to this research. Topics covered include egg objects, acquisition processes, methods, results, and conclusions, as well as state-of-the-art comparisons of our articles.

Based on previous research, identification of egg fertility on hatching machines has been carried out—research on determining the feasibility of eggs with a semi-transmitting mode. Research [9] uses hyperspectral line-scan imaging. The analysis of this study uses the Principal Component Analysis (PCA) method, and image processing uses a co-texture. The results obtained from 88 eggs tested by this method gave 99% accuracy. Eggs that are processed can show significant differences between blood vessels that can be fertilized or not.

CNN classification can distinguish fertile and dead eggs in the ninth day hatching process [3]. This method is combined with channel weighting (squeeze-and-excitation module) and joint supervision for the classification process. The result is eggs can be sorted according to existing conditions with a percentage of success of 98.8%. This research is a reference and differentiator from the research we do. Our research is based on segmentation for the detection process of egg fertility.

Prediction of egg fertility can be made with ANN [10]. Egg fertility was predicted using a dataset of 150 chicken eggs. The prediction process with several image processing methods, including preprocessing, color segmentation, classification algorithms with pattern recognition (ANN). The predictions made have an accuracy of 97% of all processes. The difference with our research is the segmentation method used, and the final process to show the presence/absence of an embryo.

Besides, egg image processing related to embryos based on thermal imaging-based images [11]–[14], hyperspectral imaging [15], [16], and digital cameras with the concept of candling [17] has been extensively studied. This research uses image processing with a camera using the concept of candling. Thus, the related research base used as a reference is the identification/detection of egg embryos with digital cameras or the like.

This research refers to previous studies. Associated with image processing in egg image processing associated with egg embryos [18]–[21]. In this study using the concept of segmentation with K-means
segmentation based on Lab color space. Besides, the process of embryo detection is based on grayscale images by image processing using image enhancement, morphology.

3. Materials and Methods
This section explains the methods and stages associated with the segmentation process with color imagery and continued with its grayscaling [22]. Using the method is divided into two main parts to get segmentation results. The first part is to process images based on color images using Lab color space to get segmented color image results. In the second part, this stage is a continuation of the first stage carried out to clarify the object of the embryo in grayscale egg images. This last stage produces images of embryos that are detected to have image clarity. The method used uses image enhancement and morphology.

![Figure 1](image)

**Figure 1.** The image segmentation process is based on (a) Lab colors and sequences based on (b) grayscale image conversion

3.1. Tools and process of image acquisition
Image acquisition is the primary initial stage of image processing. The aim is to digitize objects into space that can be processed by a computer. The acquisition in this article, as has been done in previous studies [18], [19], [23]. Tools used in the study include smartphone cameras and LED lights. The acquisition process requires a dark place/room condition so that it can be processed at night or in a room without light.

3.2. Lab color space on image preprocessing
Image preprocessing in the initial stages uses the conversion of color images (RGB) into Lab color images. Lab color images use the concept of coloring based on luminance or lightness (L) of white-black and chromatic color components (a. red-green and b. yellow-blue) [24]. The color space lab is a development of CIEXYZ [25], with L values represented in the values 0 (black) and 100 (white). As for the chromatic color representation (red-green and yellow-blue), each in the range of -128 to 128. Labs have the concept that colors should not be based on the device displayed (device-autonomous).

The Lab Model is a simple color model, where time is an absolute criterion that compares all color models. The process of changing the Lab color model from RGB requires the conversion of CIEXYZ to Lab. The conversion process requires the calculation process as in the (1)-(8) [25], [26] with \( \sigma = 6/29 \).

\[
L^* = 116g \left( \frac{Y}{Y_n} \right) - 16 \quad (1)
\]

\[
a^* = 500 \left( g \left( \frac{X}{X_n} \right) - g \left( \frac{Y}{Y_n} \right) \right) \quad (2)
\]

\[
b^* = 200 \left( g \left( \frac{Y}{Y_n} \right) - g \left( \frac{Z}{Z_n} \right) \right) \quad (3)
\]
\[ G(t) = \begin{cases} \frac{\sqrt[3]{t}}{3\sigma^2} + \frac{4}{29}, & \text{if } t > \sigma^3 \\ \end{cases} \]  (4)

\[ X1 = X1_ng^{-1}\left( \frac{L^*+16}{116} - \frac{a^*}{500}\right) \]  (5)

\[ Y1 = Y1_ng^{-1}\left( \frac{L^*+16}{116}\right) \]  (6)

\[ Z1 = Z1_ng^{-1}\left( \frac{L^*+16}{116} + \frac{b^*}{500}\right) \]  (7)

\[ G(t) = \begin{cases} \frac{\sqrt[3]{t}}{3\sigma^2} + \frac{4}{29}, & \text{if } t > \sigma^3 \\ \end{cases} \]  (8)

3.3. K-means segmentation process

The segmentation process in this study uses the concept of clustering. The image is divided into three parts, namely the background, eggs, and yolk eggs. This segmentation process uses the K-means algorithm with a value of k = 3.

The steps in the k-means process [27], [28] are shown as follows:
1. Determine the K value used in the clustering process
2. Randomly selecting K centroid points for initial determination
3. The process of grouping data by forming K clusters with the centroid point of each cluster which is the centroid point selected earlier. This process is done by calculating the distance (9), namely Euclidean Distance.

\[ d(i,j) = \sqrt{\sum_{k=1}^{p}(x_{ik} - x_{jk})^2} \]  (9)

Euclidean distance (\( d(i,j) \)) is the distance of the object between i and j. The calculation process uses the p-value as a dimension of data that illustrates the number of values to be processed. The Euclidean distance calculation will reduce the coordinates of object i (\( x_{ik} \)) with object j (\( x_{jk} \)) on the same dimension k. The centroid point renewal process is calculated by the formula (10).

\[ \mu_k = \frac{1}{N_k} \sum_{q=1}^{N_k} x_q \]  (10)

The calculation of centroid points in the k-cluster (\( \mu_k \)) is processed by adding all the data to the q (\( x_q \)) divided by the amount of data in the k-cluster (\( N_k \)). The condition used is to use the value q = 1 up to a lot of data.

4. Centroid point value updated to get the best value
5. Repeating processes 3 and 4 until the value of the centroid point is consistent/stable (unchanged)

3.4. Image grayscaling and enhancement

This study uses grayscaling to convert the image results of color segmentation into grayscale images. The conversion process uses (11). Each color component (Red (R), Green (G), and Blue (B)) is used to calculate the average to a grayscale image. The mean of these images can be calculated with the same value or different according to the color composition. Red is multiplied by 0.2989, green is multiplied by 0.587, and blue is multiplied by 0.1141.

\[ G' = 0.2989 \times R + 0.587 \times G + 0.1141 \times B \]  (11)

Image enhancement is used to improve the image [29] before processing [30]. Image enhancement in this study uses a combination of Histogram Equalization (HE) and Contrast Limited Histogram Equalization (CLAHE). The image will be improved based on its histogram value [31]. The histogram is processed using grayscale images.
The HE process is used because of the spread of intensity of pixels in uneven images, such as images that are too dark/bright. Repair HE (32) is processed using (12).

\[ H(X_k) = \frac{n_k}{W}, \text{ where } 0 \leq k \leq L - 1 \]  

(12)

HE processing in grayscale images using (12) where \( L \) is the degree of gray, \( n_k \) is the number of pixels with gray degrees \( k \) (dynamic range \( \in [X_0, X_{(L-1)}] \)), and \( W \) is the number of all pixels. CLAHE is the development of HE whose histogram has a limit value (33) (with a maximum height limit of the histogram). CLAHE is calculated with a histogram boundary clip limit shown as in (13).

\[ \beta = \frac{M}{n} \left(1 + \frac{a}{100}(s_{max} - 1)\right) \]  

(13)

Based on (13), the value of \( M \) is the size of the region size. \( n \) is the value of grayscale, and \( a \) is a clip factor as an addition to the limit of the histogram, which is range 0-100.

3.5. Morphological method

Image morphology aims to change the shape of the original image and improve the results of segmentation. This method is processed using a two-image approach, namely, binary and grayscale images. Morphological processes are available in many ways, but this research uses dilation, morphology 'thicken', edge detection.

Dilation is a morphology to enlarge the size of the object segments by adding layers around the object (thickening of objects in the image). This thickening uses the form of structuring element (strel) lines or lines. In this study, the dilation used is the 'line' strel with a length of 1 and 45 degrees. The dilation process is processed by surgery (14).

\[ A \oplus B \]  

(14)

In addition to the thickening, the next process is thickening. Thickening is used to thicken the selected area of the foreground pixels in the binary image. Its application can be made by determining the estimated convex hull (shape) and determining the object's skeleton (15)-(16).

\[ A \odot B = A \cup (A \odot B) \]  

(15)

\[ A \odot \{B\} = ((...((A \odot B^1) \odot B^2)...) \odot B^n \]  

(16)

In edge detection, the processed image is a similar image with a different brightness level. Detection results in the form of edges of objects are detected in the image. Thus, objects can be marked so that the image details can be improved due to imperfect acquisition processes (for example, motion blur). In this study, we were using a canny operator for optimal edge detection with Gaussian Derivative Kernel. So the results given show a smooth edge detection because through noise filtering from the initial image. In the edge detection process using the canny operator, there are several processes, including grayscaling, Gaussian filter, intensity gradients, Non-Maximum Suppression, Double Thresholding, Edge Tracking by Hysteresis, and Cleaning Up. The process is done using Matlab with code as in (17).

\[ \text{Ed}_\text{canny}=\text{edge}(\text{black_white_image}, \text{'canny'}); \]  

(17)

Edge detection produces margins that detect objects. In this study, segmentation in the yolk section, embryos were identified in it. The results show the object visible with the detection.

3.6. Evaluation using SSIM and MSE

In the final evaluation in this study, it is necessary to check the structural similarity index method (SSIM). SSIM is a perception-based method concerning image degradation on changes in perception in structural information (34). SSIM processes calculations based on luminance, contrast, and structure. The SSIM index is calculated on various image windows. The size between two \( x \) and \( y \) windows with the general size \( N \times N \). The SSIM formula can be seen in (18).
In addition to SSIM, evaluations are carried out using MSE (Mean Squared Error), and the calculation is shown in (19).

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [f(i,j) - g(i,j)]^2$$  

(19)

4. Results and Discussion

The discussion in this section is more about the implementation of methods and analysis related to segmentation with color images and continued with its grayscaling. This article is divided into two main parts to get segmentation results. The first part process the image based on the color of the image using the Lab color space to get segmented color image results. In the second part, this stage is a continuation of the first stage carried out to clarify the object of the embryo in grayscale egg images. This last stage (result of the research) produces images of embryos that are detected with clear images. The method used uses image enhancement and morphology.

4.1. Image Acquisition and Preprocessing

Based on the image acquisition, the initial stage aims to digitize objects into space that can be processed by a computer. Smartphone cameras and LED lights is used to capture image on a dark place/room condition. This process should at night or in a room without light. The results of image acquisition in this study were in the form of color images (Figure 2). The resulting image size is 892x1191, as shown in Figure 2 (a). The original image is processed by cropping to get the image with the whole egg object (Figure 2. (b)). The purpose of this cropping is to eliminate background objects that are not needed.

![Figure 2](image-url)

Figure 2. The initial image is used in research with (a) image of the acquisition and (b) image of the cropping from the original image

Cropping image becomes a source for further image processing, where this image has a size of 582x778. This part is more highlighted by the object than the processed mind. The image in Figure 2. (b) is an image of an egg detected by an embryo. The embryo egg image [35], [36] has a characteristic in the egg circle, and there is a network that looks faint. The next process will clarify the picture so that the components of the embryo are visible.

4.2. K-means segmentation based-on lab color space for embryo egg detection

Image preprocessing in the initial stages uses the conversion of color images (RGB) into Lab color images. This conversion is to divide the domain according to the factors of the color space Lab. The L domain in the Lab can be shown in Figure 3. (a) shows the luminance of the image. In contrast, the fields a (Figure 3.(b)) and b (Figure 3.(c)) show their particular combinations in red-green and yellow-blue sequences.
Figure 3. RGB to Lab conversion image for each component (a) L (luminance), (b) a (red-green), and (c) c (yellow-blue).

Based on the image of the acquisition results, the results have been cropped according to the egg object (Figure 2.b). Lab results (Figure 3) can be combined into one image, as in Figure 4. (b).

Figure 4. The results of the processes of the first stages of the image (a) the initial image (the results of cropping), (b) the process of image conversion with Lab color space, (c) clustering with K-means, (d) the first cluster, (e) the second cluster, and the third cluster, and (g) the result of segmented color images
Based on Fig 4, the result of the Lab color space process got the image segmented. Segmentation of the embryo detection and edge detection of the egg. The last method of detection is cropped and converted to image grayscale. The grayscale result of this process was processed by image enhancement and morphological process.

4.3. Grayscale of image segmented result (first stage)
In the second stage, image segmentation results (Figure 5. (a)) based on color are processed by cropping (Figure 5 (b)), and grayscaling (Figure 5. (c)). The purpose of this process is to change the color image of segregation results in grayscale images.

![Figure 5](image)

**Figure 5.** The resulting image (a) segmentation by color, (b) is processed by cropping, and (c) is converted to grayscale

The grayscale image provided is used for image enhancement and morphology of the image at a later stage. The grayscale image in Figure 5. (c) is obtained by dividing each color (RGB) into one color (grayscale) according to (1).

4.4. Image enhancement and morphological process for embryo egg detection
Grayscale image results are grayscale images. Grayscale images are processed using image enhancement. Image enhancement in this study applies a combination of image improvement based on the histogram. The method used in image improvement is HE and CLAHE. The results of the HE process are shown in Figure (a). Then it is processed again with the repair using the CLAHE method. The results of this quality improvement give a picture of an egg yolk containing embryos.

![Figure 6](image)

**Figure 6.** The results of image processing with image enhancement with the methods (a) HE, (b) CLAHE, and Morphological methods with dilation with the 'line' and 'thicken' strings, and (e) edge detection using the canny method
The image enhancement becomes a reference for morphological processing. The result of the image enhancement is processed in dilation with a combination of 'line' and 'thicken' strings. The 'line' string provides clearer imaging results compared to previous imagery. This processing requirement grayscale image must first be converted into a black and white image (BW).

BW images are processed according to processes (4)-(6) to obtain image results such as Fig. 6. (a) for the image improvement process with Histogram Equalization. Contrast the difference in the initial grayscale image with the BW results with HE obtained by clearer image characteristics. The object shown is the embryo from the egg image. The second improvement process is done by using CLAHE so that a smoother and brighter image is obtained.

4.5. Image Evaluation using MSE and MSSIM
Based on the research data tested, image testing was carried out using Structural Similarity (SSIM). The SSIM method shows that embryonic egg image data testing results in SSIM values close to 1, with an average value of 0.9979.

The SSIM calculation in an embryo egg image has a value distribution with a range of values between 0.9257 to 1. Thus, based on the ssim distribution chart, the average value of the SSIM (MSSIM) produced is 0.9979. This number shows that the resulting value gives excellent results where the information conveyed does not have much difference. Besides, the evaluation uses MSE to check errors based on the output image from the initial image based on the Bw image. MSE produced is equal to 0.0486. These results indicate that the resulting image still has similarities with the initial image so that it can be used as a reference for the segmentation process for the detection of embryos in eggs.

5. Conclusion
Based on the experiments that have been done, K-means Segmentation with Lab color space can group images into several parts. The image of the processed egg is divided into three parts, namely, background, egg, and yolk. Thus, the color space Lab process with k-means can computerize image objects according to the criteria of image uniformity differences. The result can be clarified with the second stage using grayscale image-based processing methods so that the embryo in the egg yolk image can be seen clearly. The evaluation uses MSE and MSSIM, with values of 0.0486 and 0.9979; this can be used as a reference that the results obtained can indicate the detection of embryos in egg yolk.

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