**Accredited by National Journal Accreditation (ARJUNA) Managed by**
Ministry of Education, Culture, Research and Technology with **Second Grade (Sinta 2)**
**since year 2021 to 2026** according to the decree No. 158/E/KPT/2021

Published online on the journal's webpage: **http://jurnal.iaii.or.id**

**JURNAL RESTI**
**(Rekayasa Sistem dan Teknologi Informasi)**
Vol. 5 No. 6 (2021) 1062 - 1069 ISSN Media Elektronik: 2580-0760

# Detection of Chicken Egg Embryos using BW Image Segmentation and Edge Detection Methods

Shoffan Saifullah[1], Andiko Putro Suryotomo[2], Yuhefizar[3]
[1,2]Informatics, Faculty of Industrial Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta
[3]Program Studi Manajemen Informatika, Jurusan Teknologi Informasi, Politeknik Negeri Padang
[1]shoffans@upnyk.ac.id*, [2]andiko.ps@upnyk.ac.id, [3]yuhefizar@pnp.ac.id

**Abstract**

This study aims to identify chicken egg embryos with the concept of image processing. This concept uses input and output in images. Thus the identification process, which was originally carried out using manual observation, was developed by computerization. Digital images are applied in identification by various image preprocessing, image segmentation, and edge detection methods. Based on these three methods, image processing has three processes: image grayscaling (convert to a grayscale image), image adjustment, and image enhancement. Image adjustment aims to clarify the image based on color correction. Meanwhile, image enhancement improves image quality, using histogram equalization (HE) and Contrast Limited Adaptive Histogram Equalization methods (CLAHE). Specifically for the image enhancement method, the CLAHE-HE combination is used for the improvement process. At the end of the process, the method used is edge detection. In this method, there is a comparison of various edge detection operators such as Roberts, Prewitt, Sobel, and canny. The results of edge detection using these four methods have the SSIM value respectively 0.9403; 0.9392; 0.9394; 0.9402. These results indicate that the SSIM values of the four operators have the same or nearly the same value. Thus, the edge detection method can provide good edge detection results and be implemented because the SSIM value is close to 1.00 (more than 0.93). Image segmentation detected object (egg and embryo), and the continued process by edge detection showed clearly edge of egg and embryo.

Keywords: embryo egg detection, image processing, image segmentation, image adjustment, image enhancement

## 1. Introduction

The livestock industry has developed a lot in various ways, one of which is detecting chicken egg embryos. This detection aims to check and find out the egg embryos in the incubator. In addition, this process aims to maximize the egg hatching process. Eggs that are not embryonated can be used for other purposes such as consumption. This process is carried out at a maximum time of 1 week [1] to get maximum results (the embryo is visible) [2].

The egg embryo detection process uses various segmentation [3] and classification methods [4], [5]. This detection process uses image processing to determine the presence of embryos in eggs [6]. The identification process [7] in previous studies used machine learning methods [8], both supervised [9] and unsupervised learning [10]. The process starts by taking the image used as a dataset. Image capture used thermal [11], [12] or digital cameras [13], [14]. This study using a dataset of image acquisition using a smartphone camera based on a digital camera. Acquisition using an additional flashlight tool for the candling process [15] to get an image that shows the egg's contents.

The segmentation used is conversion to BW (such as thresholding) with a threshold value of 128. Then the following process is saturated detection to clarify the detected embryo objects. It is what distinguishes it from previous studies using methods such as k-means and morphology [16], [17], thresholding [3], otsu [18], Fuzzy logic [19], watershed[20], region generation [21], Differential Interference Contrast (DIC) based Shape Index and Ellipsoid-Fitting [22].

The concept of edge detection in egg embryo detection (fertility) has been carried out only by using canny detection [16]. The results were able to detect the edges of the embryos as a result of k-means segmentation. In addition, canny detection [23] is implemented to identify the fertility of native chicken eggs based on grayscale images. This research develops image preprocessing with several methods to detect better, such as image

Accepted by Editor: 04-10-2021 | Final Revision: 15-11-2021 | Online Publication: 30-12-2021

adjustment and enhancement. This study uses four edge detection operators with segmentation based on BW images. Thus, this research focuses on the detection of embryo edges.

In addition, Sobel can perform the outline detection process of the egg object [24], [25]. This study also detects the embryonic object. Edge detection that is widely used include canny detection [16], [17], [23], [26]. In addition, segmentation can solve poultry problems such as detecting eggs, poultry, carcasses, especially in image processing. This study aims to detect the presence of egg embryos using basic segmentation with BW images and edge detection using methods such as Roberts, Prewitt, Sobel, and Canny.

The problem that we raise in this research is the detection of embryo eggs in image segmentation. Several processes are carried out, from manuals to several studies that have developed embryo detection by segmentation and classification with various methods and are still being developed to get more precise and better results. This study focuses on improving the image segmentation of embryonated chicken eggs by combining BW image conversion and object edge detection.

This article is presented in four main sections. The first section explains the introduction, background of the problem, differences in previous research, and research objectives. The solution is carried out by applying the image processing methods presented in the second section. The third section presents the analysis of the results and discussion of this research. Lastly is the conclusion section.

## 2. Method

This study uses the concept of image processing with the object in the form of an image of a chicken egg embryo. Image of chicken egg embryo using the dataset from previous research. The identification process steps using edge detection with the previous process are image preprocessing (adjustment and enhancement) and image segmentation (BW-image segmentation (Figure 1)).

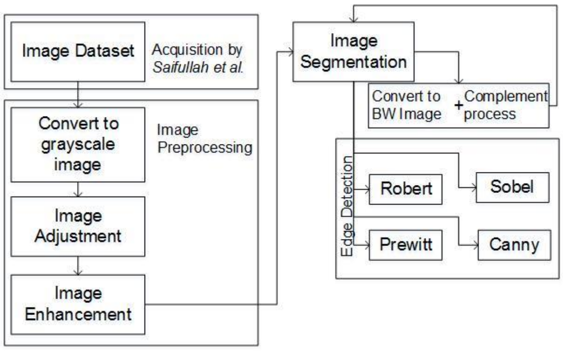


Figure 1. Steps for the detection of Chicken Egg Embryo using Image Processing

The image dataset is a color image (RGB) that has been cropped (Figure 2. (b) [27]). In the previous process, we captured an object (chicken egg) using candling process, and the design of this process is shown in Figure 2. (a) [28], [29]. Based on this process, the digital image was created and processed by other image preprocessing methods.

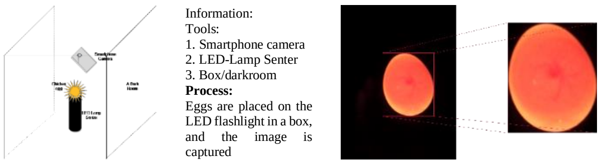


Figure 2. (a) Image Acquisition and (b) Cropping Process

Image preprocessing in this study is image grayscaling, image adjustment, and image enhancement [20], [30]. Image grayscaling is a method for converting RGB images to grayscale. RGB images have three color channels, namely red (R), green (G), and blue (B). The conversion process uses (1) [31] to get a gray level color gradation with a value range between 0-255.

$$gray = 0.2989 * R + 0.587 * G + 0.1141 * B \qquad (1)$$

Grayscale images need to be processed using image adjustments. This method aims for color correction (setting). In this study, image adjustment maps the intensity value of I to a new value of J based on the image's lowest and highest intensity, which maps to the value between the lowest and the highest of the average intensity. Image adjustment uses linear mapping to get a new intensity value in the histogram of the image used. Image adjustment calculates the factor value (F) of the image contrast correction (2) with a floating-point value. The value of C indicates the level of contrast. So this process is continued by using a contrast enhancement (R) on each color component (3).

$$F = \frac{259(C+255)}{255(259-C)} \qquad (2)$$

$$R' = F(R-128) + 128 \qquad (3)$$

The result of color improvement with image adjustment becomes the input for image enhancement [32]. Image enhancement uses two combined methods of Histogram Equalization (HE) and its derivative Contrast Limited Adaptive Histogram Equalization (CLAHE). The use of this method is based on the previous research, that the resulting image shows better results than single methods or other combinations [29], [30], [33]. This process uses the concept of image histogram modification. The calculation of the two methods uses (4) for HE and (5) for CLAHE. The next step is to combine the two using (6) to obtain a better image result from these methods.

$$hi = \frac{n_i}{n}, i = 0, 1, 2, \dots, L-1 \qquad (4)$$

$$\beta = \frac{M}{n}(1 + \frac{\alpha}{100}(s_{max} - 1) \qquad (5)$$

DOI: https://doi.org/10.29207/resti.v5i6.3540

$$hybrid\ CLAHE - HE = \beta \oplus h_i \quad (6)$$

HE can improve image quality using histogram alignment generated by images [34], [35]. The image matrix is used as a reference to get the total number of pixels (n). This method will divide the image based on the number of gray pixels (ni) with pixels up to the maximum gray value (L). CLAHE is an extension of HE [34] with a limit value based on the maximum height of the histogram [36]. The constraint applies the clip limit formula to obtain contrast based on the kernel weighting of each neighboring pixel (5). So that the CLAHE method can eliminate noise and improve its quality, this clip boundary uses the area size (M), grayscale value (N), and clip factor (a) in addition to the histogram boundary (0-100). Based on previous research, comparing the HE and CLAHE methods and their hybrids, where the different histograms show the differences in the image - the best-distributed histogram [37] is used in the segmentation method. Hybrid CLAHE-HE has an optimal histogram distribution [29].

Image segmentation was used to separate objects and the background or other parts of segments (image). Methods on image segmentation have been implemented based on this case, like Threshold, edge detection, Otsu, and others [38]. As in the previous research, we used the concept of thresholding that used the BW image conversion.

Segmentation used the results of image quality improvement. This process only used the conversion of a grayscale image into a BW image [13], [39] by changing the value of a grayscale image (range 0-255) into a BW image with a limited median value. Matrix values above 128 are changed to 255, and below 128 are converted to 0. Thus, the resulting value can be converted into binary values (0 and 1). In addition, there is the addition of complement (the opposite to clarify the picture of the egg embryo.

The final process is edge detection by applying four approaches: Roberts, Prewitt, Sobel, and Canny [33]. These operators are calculated based on gradient (7) with different kernels. Roberts operator using a 2x2 pixels kernel.

$$G = \sqrt{R_x^2 + R_y^2} \quad (7)$$

$$R_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}; R_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

The Prewitt operator in its implementation uses a kernel sized 3x3 pixels with values as in the P matrix ($P_x$ and $P_y$). Likewise, the Sobel operator, the kernel used is 3x3 pixels in size; the difference is its value. The Sobel operator kernel uses an S ($S_x$ and $S_y$) matrix.

$$P_x = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}; P_y = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

$$S_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}; S_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

The canny operator is an optimal edge detector and produces smooth edges that are filtered using the Gaussian Derivative Kernel [31]. This method uses a Gaussian filter to smooth the image and reduce the edge detector's apparent noise effect (8).

$$H_{ij} = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{\left(i-(k+1)\right)^2 + \left(j-(k+1)\right)^2}{2\sigma^2}\right) \quad (8)$$
$$1 \geq i; j \leq (2k+1)$$

The Canny edge detection algorithm is processed in several steps, namely:

1. Use a Gaussian filter to smooth the image and remove noise
2. Find the intensity gradient of the image
3. Use gradient magnitude threshold or lower bound suppression to eliminate false responses to edge detection
4. Apply double Threshold to define potential edge
5. Trace edges with hysteresis: Edge detection is performed by suppressing all weak edges and not connecting to firm edges.

## 3. Results and Discussion

This study produces a segmented image and edge detection of the object of the embryo image of a chicken egg. The image is obtained by various processes, including improving the color, quality, and dataset segmentation. One of the sample datasets used is as shown in Figure 3. (a).

Figure 3. (a) is a cropped image of the dataset used in this study. The image is an RGB image and has a single egg object. The image is processed by several steps, as shown in Figure 1, and shows the following detail.

### 3.1. Convert to Grayscale Image

Digital images (from datasets) are processed by grayscaling to get an image with a gray level between 0-255. The conversion process uses (1) so that an image like Figure 3. Figure 3 shows that the three color components converted into a grayscale image with a grayscale range between 0-255. The converted image is based on the number matrix of the image according to the size [40] and then calculated. The visible image is as shown in Figure 3. (c), (d), and (e) for each RGB color.

Based on Figure 3, we analyzed each color of the image (Figure 3. (a)) using the following matrix. The matrix was cropped on the part of an image by 5x5 pixels. The followings matrix is samples of image representation on matrix.

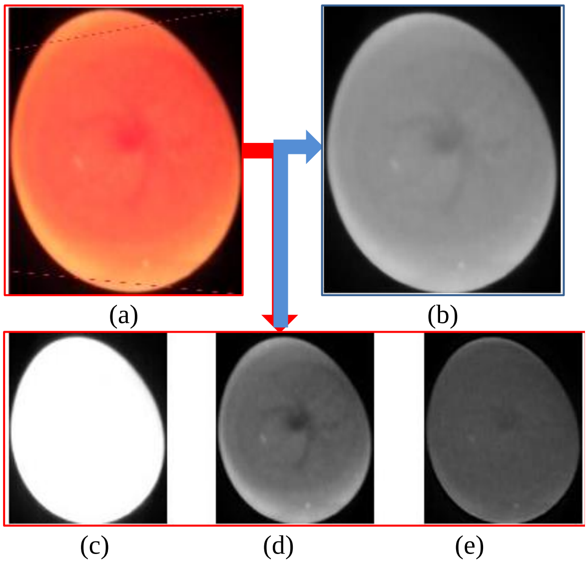


Figure 3. Conversion Process (a) Color Image from three Color Image Components (c) Red, (d) Green, (e) Blue which Produces Grayscale Image

$$R=\begin{bmatrix}255 & 255 & 254 & 255 & 255\\ 255 & 254 & 255 & 255 & 255\\ 255 & 255 & 255 & 255 & 255\\ 255 & 255 & 255 & 255 & 255\\ 255 & 255 & 255 & 255 & 255\end{bmatrix}$$

$$G=\begin{bmatrix}93 & 92 & 92 & 97 & 98\\ 92 & 93 & 96 & 98 & 99\\ 97 & 97 & 101 & 102 & 105\\ 100 & 102 & 106 & 108 & 109\\ 103 & 105 & 110 & 114 & 117\end{bmatrix}$$

$$B=\begin{bmatrix}68 & 68 & 69 & 70 & 68\\ 71 & 69 & 72 & 70 & 69\\ 73 & 71 & 74 & 70 & 70\\ 73 & 72 & 73 & 70 & 71\\ 72 & 72 & 72 & 70 & 72\end{bmatrix}$$

Each matrix (R, G, and B) calculate by (1), which R*0,2989+ G*0,587+B*0,1141. Thus, the calculation is shown in the following matrix (Gray). The result will be

$$Gray=\begin{bmatrix}139 & 138 & 138 & 141 & 142\\ 138 & 138 & 141 & 142 & 142\\ 141 & 141 & 144 & 144 & 146\\ 143 & 145 & 148 & 148 & 148\\ 145 & 146 & 151 & 151 & 188\end{bmatrix}$$

The result of the matrix calculation is rounded up, which is close to the integer value. If the value is more than 0.5, it is rounded up. If the value is less than 0.5, it is rounded down, and if the value is equal to 0.5, then if the absolute value is even, it is fixed, and if it is odd, it is rounded up.

### 3.2. Image Preprocessing After Grayscaling

Image preprocessing after converting the image to grayscale is image adjustment and image enhancement. Image adjustment used in this study aims to increase the contrast of the image. Based on Figure 3. (b), the result of the grayscaling showed that the object (especially the egg embryo) was not clear. Thus, the process of image adjustment used analysis of the frequency of the histogram. The new contrast of the image adjustment result (Figure 4. (a)) was higher than the previous image (Figure 3. (b)).

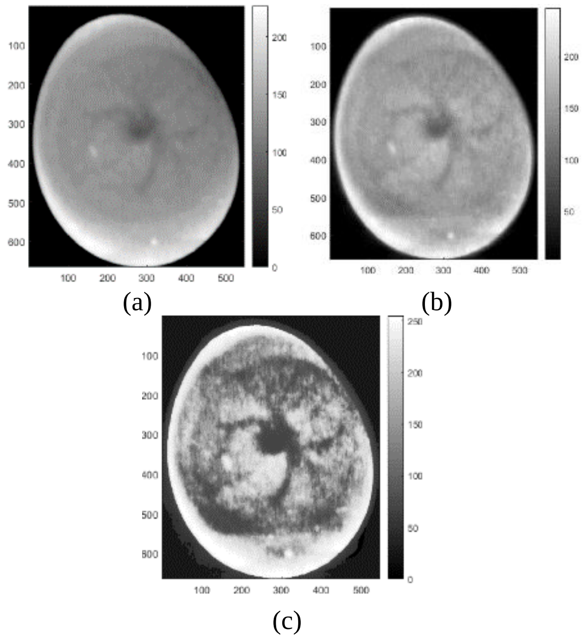


Figure 4. Image Preprocessing using (a) Image Adjustment and Image Enhancement (b) CLAHE, (c) CLAHE-HE

The histogram comparison of the input image and the adjustment image is shown in Figure 5. The input image's histogram is in the distribution position of the intensity values on the left (close to 0). While the histogram of the adjustment image has changed, that is the distribution shifts to the right (closer to 255).

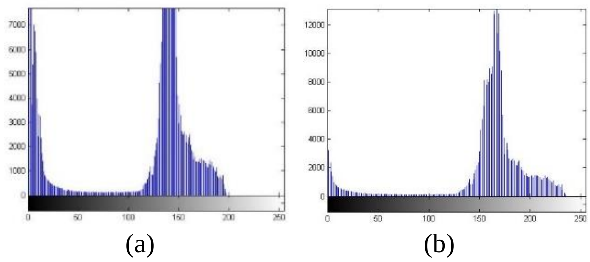


Figure 5. Histogram (a) Input Image with a maximum range of 213 and Image Adjustment Results with a maximum range of 255

The histogram Figure 5 shows that with image adjustment, the resulting image has a different quality, namely the range of values is increased and has a value close to 255. From Figure 5. (a), the distribution of histogram values is at points 0-50 and 110-200. Although the 50-110 range is low, this graph shows that the resulting image quality is low. After processing with image adjustments, the resulting range spreads to 255, with the graph spreads up from low to high and shifts to the right (closer to 255) so that the resulting quality has improved.

DOI: https://doi.org/10.29207/resti.v5i6.3540

However, this image should be improved to get an image with precise characteristics of the embryo image object. The method used is an image enhancement that has also improved the image quality based on the alignment of the resulting histogram. Figure 4. (b) is an image quality improvement based on the image contrast limitation. Thus, the results obtained have improved quality compared to the previous image (Figure 4. (a)). However, based on previous research that the optimal image enhancement is CLAHE-HE, this research uses the hybrid method. This method shows more detailed results than other methods (CLAHE or HE or another hybrid) and image adjustments. It can also be shown as in the CLAHE-HE result Histogram as in Figure 6.

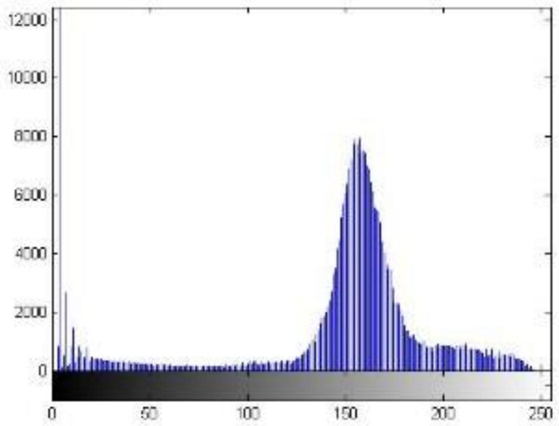

Figure 6. CLAHE-HE Histogram of Embryo Egg Image Sample

Image enhancement was performed using a CLAHE-HE combination. This method can show the object image in detail, especially the image of the embryo in the chicken egg.

3.3. Image Segmentation

The segmentation uses the BW conversion method and its complement to obtain an image that detects the chicken egg embryo object. The segmentation process is carried out using the complement of the CLAHE-HE repaired image as shown in Figure 7. (a), where the image shows a negative image. The image matrix is changed using the maximum grayscale image threshold (255) minus each matrix value. Figure 7. (a) has an intensity range between 0-255 and is seen in the distribution of values (right of image). So it needs to be converted in the image segmentation process.

In this study, the segmentation used the conversion of grayscale images into black and white images. The change process was based on the middle threshold value of the gray degree level (256/2=128). The pixel intensity value of more than 128 is changed to 255, while the others were changed to 0. this segmentation produced a BW image, as shown in Figure 7. (b). This conversion also shows a binary image conversion, where the resulting intensity values have values of 0 and 255, which are converted to 0 and 1. The range of 0 and 1 are shown in Figures 7. (b) and 7. (c).

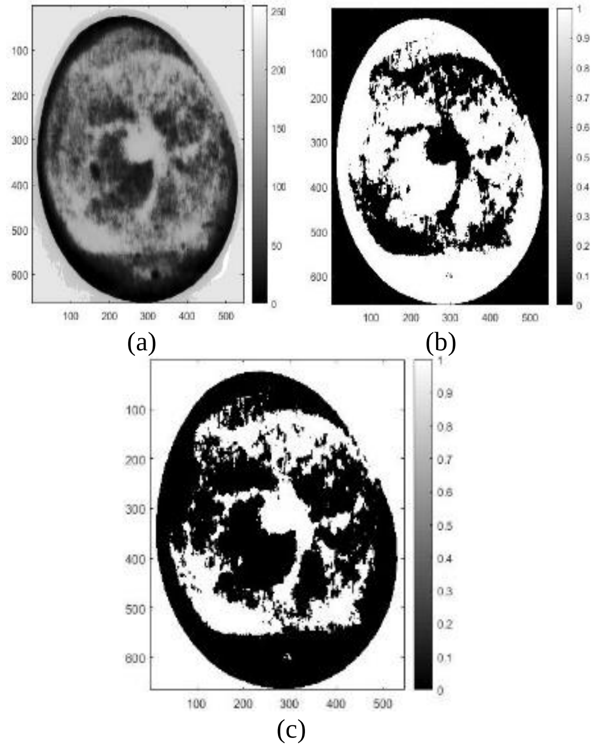

Figure 7. Image Segmentation Based on (a) Complemented Grayscaling Image and BW Image (b) Original and (c) Complementary

The last process in this segmentation is the complement of the BW image. This process aims to show the pattern of the object obtained, namely, the background is white, and the object (eggs) is black, with the characteristics of the embryo being white.

3.4 Edge Detection for Identification on Embryo Chicken Egg

Edge detection uses four operators, namely Roberts, Prewitt, Sobel, and Canny. In its implementation, edge detection provides an overview of the detection of chicken egg embryos. It showed their characteristics by being marked as a net or as a root. The four methods produce good detection, where the edge detection results clearly show eggs with embryos with the appropriate characteristics, as shown in Figure 8.

Based on Figure 8, edge detection results in edge detection of general and specific objects. The outermost oval circle indicates a chicken egg. At the same time, the embryo object is shown as network lines or roots in a circle. The picture shows that the results obtained have a pattern that is not much different. However, each image from the operation of the four operators has a different distribution of values.

DOI: https://doi.org/10.29207/resti.v5i6.3540

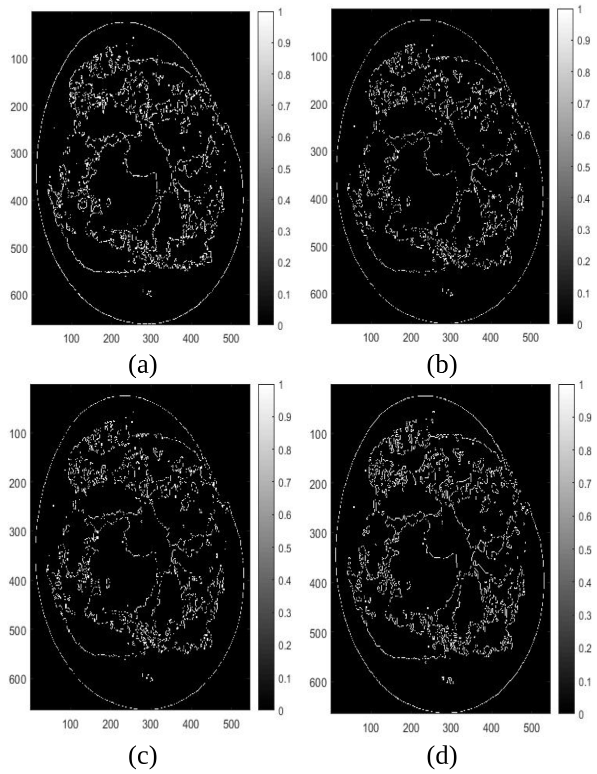


Figure 8. The Results of Edge Detection Using Operator (a) Roberts, (b) Prewitt, (c) Sobel, and (d) Canny

In these images (Figure 8), Edge detection using the Roberts, Prewitt, and Sobel operators applies a Magnitude Gradient. So the results obtained show the results of object edge detection in detail from the outer object (eggs and embryos). Including detection with the canny operator has detailed detection results, in which the distribution of the resulting values is 0 and 1. Based on the size image (665x545 pixels), the distribution of the total value is 362425. In detail from Figure 8, the distribution of values 0 and 1 are obtained in Table 1.

Table 1. Distribution of Values (0 and 1) on Edge Detection of the 4 Operators on the Output Image (Results).

| Operator | Total of | | Total |
|---|---|---|---|
| | 0 | 1 | |
| Roberts | 345727 | 16698 | 362425 |
| Prewitt | 349564 | 12861 | 362425 |
| Sobel | 349084 | 13341 | 362425 |
| Canny | 346566 | 15859 | 362425 |

Based on Table 1, the distribution of 0 values indicates that the total intensity is 0 (dark, which is the background). Meanwhile, the value 1 indicates the distribution value of 1 (brightness, which is the edge of the object). The most extensive distribution of 1 (object) value is the Roberts method. However, the distribution value and the line detection results show objects that match their characteristics from the four operators.

The object can be outlined influenced by the previous process, namely segmentation. Then in this study, we checked the similarity of the resulting image structure based on the previous detection image. This process uses the SSIM method, which provides information about the similarity of detection.

### 3.5 SSIM value calculation

SSIM (Structural Similarity Index Method) is a method used to predict the quality of digital images. SSIM is used to measure the similarity between two images. SSIM has a value range from 0 to 1. In this study, the application of the four edge detection methods has a different average SSIM value, but the resulting range value is the same, which is between 0.8667-1. Details of the calculation results are shown in Table 2.

Table 2. SSIM Assessment and Value Distribution of Each Edge Detection Operator

| Operator | SSIM | Range (min-max) |
|---|---|---|
| Roberts | 0.9403 | 0.8667-1 |
| Prewitt | 0.9392 | 0.8667-1 |
| Sobel | 0.9394 | 0.8667-1 |
| Canny | 0.9402 | 0.8667-1 |

The mean SSIM values in Table 2 were obtained from single object images (embryo egg images). The resulting distribution value has a value close to 1. So that the comparison image used is an image with similarities and the information is not too different [40]. This calculation was used as a reference that the process carried out can be used for the embryo detection process based on the processes carried out up to the image segmentation.

In addition, the graph of the SSIM can be seen in Figure 9. Each operator has an SSIM distribution value, which shows the similarity with the comparison object. The distribution of the resulting values, as in Table 2, has an average SSIM above 0.93. The graph of the SSIM calculation has almost the same picture. The distribution of values has a range above 0.86 to 1.00. Based on the results of this distribution histogram plotting, the similarity values of the four egg edge detection methods can be uniform and implemented.

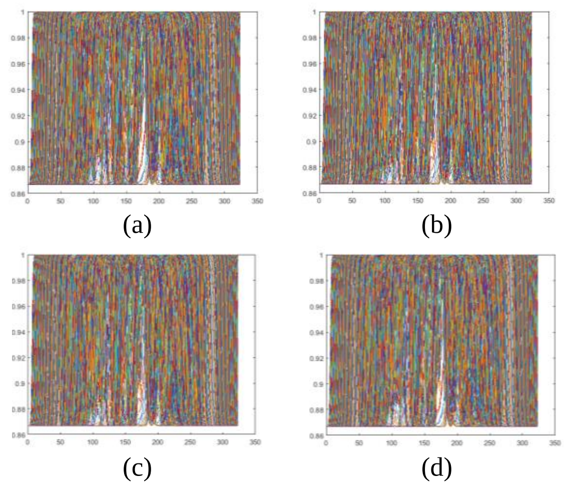


Figure 9. Distribution of SSIM values in the histogram graph of (a) Roberts, (b) Prewitt, (c) Sobel, and (d) Canny Operator

DOI: https://doi.org/10.29207/resti.v5i6.3540

Thus, the similarity of the pattern of each operator indicates that the image preprocessing and image segmentation carried out produce inputs that have good image quality. The results can be used to detect the edges of embryonic eggs with several methods, namely Roberts, Prewitt, Sobel, and Canny.

## 4. Conclusion

Based on the results of this study, the four edge detection methods were able to provide a clear picture of the contents of the embryonic egg. Edge detection can be optimized because the segmentation process (BW image) used can divide objects by their background, and embryonic objects can be detected in detail of their parts. In the evaluation of the SSIM, the resulting information gives a good score, which is more than 0.93 from each method implemented. The closer the value is to 1, the SSIM calculation indicates that the comparison results with the previous image results are similar. Thus, the methods used in this study are able to detect chicken egg embryos. In addition, the process of segmentation and edge detection can be seen clearly as part of the characteristics of chicken egg embryos.

## Acknowledgment

The author is grateful to the Department of Informatics and LPPM of the National Development University "Veteran" Yogyakarta, who have provided support and support in the research and publication of this article.

## References

[1] J. Dong *et al.*, "Prediction of infertile chicken eggs before hatching by the Naïve-Bayes method combined with visible near infrared transmission spectroscopy," *Spectrosc. Lett.*, pp. 1–10, Apr. 2020, doi: 10.1080/00387010.2020.1748061.

[2] L. Huang, A. He, M. Zhai, Y. Wang, R. Bai, and X. Nie, "A Multi-Feature Fusion Based on Transfer Learning for Chicken Embryo Eggs Classification," *Symmetry (Basel).*, vol. 11, no. 5, p. 606, May 2019, doi: 10.3390/sym11050606.

[3] S. Saifullah and A. P. Suryotomo, "Thresholding and Hybrid CLAHE-HE for Chicken Egg Embryo Segmentation," in *2021 International Conference on Communication & Information Technology (ICICT)*, Jun. 2021, pp. 268–273, doi: 10.1109/ICICT52195.2021.9568444.

[4] E. H. Rachmawanto *et al.*, "Eggs Classification based on Egg Shell Image using K-Nearest Neighbors Classifier," in *2020 International Seminar on Application for Technology of Information and Communication (iSemantic)*, Sep. 2020, pp. 50–54, doi: 10.1109/iSemantic50169.2020.9234305.

[5] K. Zhang *et al.*, "Clinically Applicable AI System for Accurate Diagnosis, Quantitative Measurements, and Prognosis of COVID-19 Pneumonia Using Computed Tomography," *Cell*, vol. 181, no. 6, pp. 1423-1433.e11, Jun. 2020, doi: 10.1016/j.cell.2020.04.045.

[6] L. Geng, Y. Hu, Z. Xiao, and J. Xi, "Fertility Detection of Hatching Eggs Based on a Convolutional Neural Network," *Appl. Sci.*, vol. 9, no. 7, p. 1408, Apr. 2019, doi: 10.3390/app9071408.

[7] S. Saifullah and Andiko Putro Suryotomo, "Chicken Egg Fertility Identification using FOS and BP-Neural Networks on Image Processing," *J. RESTI (Rekayasa Sist. dan Teknol. Informasi)*, vol. 5, no. 5, pp. 919–926, Oct. 2021, doi: 10.29207/resti.v5i5.3431.

[8] Sunardi, A. Yudhana, and S. Saifullah, "Identification of Egg Fertility Using Gray Level Co-Occurrence Matrix and Backpropagation," *Adv. Sci. Lett.*, vol. 24, no. 12, pp. 9151–9156, 2018, doi: 10.1166/asl.2018.12115.

[9] W. Lumchanow and S. Udomsiri, "Combination of GLCM and KNN Classification for Chicken Embryo Development Recognition," in *2019 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT-NCON)*, Jan. 2019, pp. 322–325, doi: 10.1109/ECTI-NCON.2019.8692272.

[10] S. Saifullah, "K-Means Clustering for Egg Embryo's Detection Based-on Statistical Feature Extraction Approach of Candling Eggs Image," *SINERGI*, vol. 25, no. 1, pp. 43–50, 2020, doi: 10.22441/sinergi.2021.1.006.

[11] Q. Tong *et al.*, "Detection of embryo mortality and hatch using thermal differences among incubated chicken eggs," *Livest. Sci.*, vol. 183, pp. 19–23, Jan. 2016, doi: 10.1016/j.livsci.2015.11.004.

[12] L. Hai-ling, C. Jian-rong, S. Li, Y. Lei-ming, and L. Meng-lei, "Research on the Discrimination of Hatching Eggs Activity Based on Thermal Imaging: A Food Nondestructive Testing Practice," *Int. J. Smart Home*, vol. 10, no. 2, pp. 175–186, Feb. 2016, doi: 10.14257/ijsh.2016.10.2.17.

[13] Sunardi, A. Yudhana, and S. Saifullah, "Identity analysis of egg based on digital and thermal imaging: Image processing and counting object concept," *Int. J. Electr. Comput. Eng.*, vol. 7, no. 1, pp. 200–208, 2017, doi: 10.11591/ijece.v7i1.pp200-208.

[14] Sunardi, A. Yudhana, and S. Saifullah, "Thermal Imaging Untuk Identifikasi Telur," in *Prosiding Konferensi Nasional Ke-4 Prosiding Konferensi Nasional Ke- 4 Asosiasi Program Pascasarjana Perguruan Tinggi Muhammadiyah (APPPTM)*, May 2016, no. May, p. 157.

[15] S. Saifullah and V. A. Permadi, "Comparison of Egg Fertility Identification based on GLCM Feature Extraction using Backpropagation and K-means Clustering Algorithms," in *Proceeding - 2019 5th International Conference on Science in Information Technology: Embracing Industry 4.0: Towards Innovation in Cyber Physical System, ICSITech 2019*, Oct. 2019, pp. 140–145, doi: 10.1109/ICSITech46713.2019.8987496.

[16] S. Saifullah, "K-means Segmentation Based-on Lab Color Space for Embryo Egg Detection," *arXiv Prepr. arXiv2103.02288*, Mar. 2021, [Online]. Available: http://arxiv.org/abs/2103.02288.

[17] A. Yudhana, Sunardi, and S. Saifullah, "Segmentation comparing eggs watermarking image and original image," *Bull. Electr. Eng. Informatics*, vol. 6, no. 1, pp. 47–53, 2017, doi: 10.11591/eei.v6i1.595.

[18] D. Indra, T. Hasanuddin, R. Satra, and N. R. Wibowo, "Eggs Detection Using Otsu Thresholding Method," in *2018 2nd East Indonesia Conference on Computer and Information Technology (EIConCIT)*, Nov. 2018, pp. 10–13, doi: 10.1109/EIConCIT.2018.8878517.

[19] J. G. C. Rancapan, E. R. Arboleda, J. L. Dioses, and R. M. Dellosa, "Egg fertility detection using image processing and fuzzy logic," *Int. J. Sci. Technol. Res.*, vol. 8, no. 10, pp. 3228–3230, Oct. 2019.

[20] S. Saifullah, "Segmentasi Citra Menggunakan Metode Watershed Transform Berdasarkan Image Enhancement Dalam Mendeteksi Embrio Telur," *Syst. Inf. Syst. Informatics J.*, vol. 5, no. 2, pp. 53–60, 2019, doi: 10.29080/systemic.v5i2.798.

[21] L. Liu and M. O. Ngadi, "Detecting Fertility and Early Embryo Development of Chicken Eggs Using Near-Infrared Hyperspectral Imaging," *Food Bioprocess Technol.*, vol. 6, no. 9, pp. 2503–2513, Sep. 2013, doi: 10.1007/s11947-012-0933-3.

[22] S. Yang, X. Han, and Y. Chen, "Three-Dimensional Embryonic Image Segmentation and Registration Based on Shape Index and Ellipsoid-Fitting Method," *J. Comput. Biol.*, vol. 26, no. 2, pp. 128–142, Feb. 2019, doi: 10.1089/cmb.2018.0165.

[23] A. A. Budiarto, M. B. Fatkhurrozi, and M. I. Setyowati,

"Implementasi Operator Canny untuk Identifikasi Fertilitas Telur Ayam Buras," *Theta Omega J. Electr. Eng. Comput. Inf. Technol.*, vol. 1, no. 2, pp. 1–7, 2020, doi: 10.31002/jeecit.v1i2.3547.

[24] C.-S. Lin, P. T. Yeh, D.-C. Chen, Y.-C. Chiou, and C.-H. Lee, "The Identification and Filtering of Fertilized Eggs with a Thermal Imaging System," *Comput. Electron. Agric. Comput. Electron. Agric.*, vol. 91, pp. 94–105, 2012.

[25] W. Qiaohua, F. Dandan, M. Meihu, and Z. Tao, "Differentiating between fertilized and unfertilized eggs prior to incubation based on oxygen flux measurement," *Int. J. Agric. Biol. Eng.*, vol. 10, no. 4, pp. 243–251, 2017, doi: 10.25165/j.ijabe.20171004.2606.

[26] W. Koodtalang, T. Sangsuwan, and A. Rerkratn, "Non-destructive Fertility Detection of Multiple Chicken Eggs Using Image Processing and Convolutional Neural Network," in *IOP Conference Series: Materials Science and Engineering*, Jul. 2020, vol. 895, no. 1, doi: 10.1088/1757-899X/895/1/012013.

[27] S. Saifullah, Sunardi, and A. Yudhana, "Analisis Perbandingan Pengolahan Citra Asli dan Hasil Croping Untuk Identifikasi Telur," *J. Tek. Inform. dan Sist. Inf.*, vol. 2, no. 3, pp. 341–350, 2016.

[28] S. Saifullah, "Segmentation for embryonated Egg Images Detection using the K-Means Algorithm in Image Processing," *2020 5th Int. Conf. Informatics Comput. ICIC 2020*, Nov. 2020, doi: 10.1109/ICIC50835.2020.9288648.

[29] S. Saifullah and A. P. Suryotomo, "Thresholding and hybrid CLAHE-HE for chicken egg embryo segmentation," *Int. Conf. Commun. Inf. Technol.*, 2021.

[30] S. Saifullah, "Analisis Perbandingan HE dan CLAHE pada Image Enhancement dalam Proses Segmentasi Citra untuk Deteksi Fertilitas Telur," *J. Nas. Pendidik. Tek. Inform. JANAPATI*, vol. 9, no. 1, 2020.

[31] S. Saifullah, A. P. Suryotomo, and B. Yuwono, "Fish Detection Using Morphological Approach Based-on K-Means Segmentation," *Compiler*, vol. 10, no. 1, Jan. 2021, doi: 10.28989/compiler.v10i1.946.

[32] A. Muhammed and A. R. Pais, "A Novel Fingerprint Image Enhancement based on Super Resolution," in *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)*, 2020, pp. 165–170.

[33] S. Saifullah, "Segmentasi Citra Menggunakan Metode Watershed Transform Berdasarkan Image Enhancement Dalam Mendeteksi Embrio Telur," *Syst. Inf. Syst. Informatics J.*, vol. 5, no. 2, pp. 53–60, Mar. 2020, doi: 10.29080/systemic.v5i2.798.

[34] Y. Xie, L. Ning, M. Wang, and C. Li, "Image Enhancement Based on Histogram Equalization," *J. Phys. Conf. Ser.*, vol. 1314, p. 012161, Oct. 2019, doi: 10.1088/1742-6596/1314/1/012161.

[35] K. G. Dhal, A. Das, S. Ray, J. Gálvez, and S. Das, "Histogram Equalization Variants as Optimization Problems: A Review," *Arch. Comput. Methods Eng.*, Apr. 2020, doi: 10.1007/s11831-020-09425-1.

[36] E. Park, S. Lohumi, and B.-K. Cho, "Line-scan imaging analysis for rapid viability evaluation of white-fertilized-egg embryos," *Sensors Actuators B Chem.*, vol. 281, pp. 204–211, Feb. 2019, doi: 10.1016/j.snb.2018.10.109.

[37] H. Yeganeh, A. Ziaei, and A. Rezaie, "A novel approach for contrast enhancement based on Histogram Equalization," *2008 Int. Conf. Comput. Commun. Eng.*, pp. 256–260, May 2008, doi: 10.1109/ICCCE.2008.4580607.

[38] H. Y. Yang, J. X. Zhao, G. H. Xu, and S. Liu, "A Survey of Color Image Segmentation Methods," *Softw. Guid.*, vol. 17, no. 4, pp. 1–5, 2018.

[39] S. Saifullah, S. Sunardi, and A. Yudhana, "Perbandingan segmentasi pada citra asli dan citra kompresi wavelet untuk identifikasi telur," *Ilk. J. Ilm.*, vol. 8, no. 3, pp. 190–196, Dec. 2016, doi: 10.33096/ilkom.v8i3.75.190-196.

[40] S. Saifullah, "Segmentation for embryonated Egg Images Detection using the K-Means Algorithm in Image Processing," *2020 Fifth Int. Conf. Informatics Comput.*, pp. 1–7, Nov. 2020, doi: 10.1109/ICIC50835.2020.9288648.

DOI: https://doi.org/10.29207/resti.v5i6.3540