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IMPROVING THE IMAGE OF A BANANA USING THE OPENING AND CLOSING METHOD

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Abstract*—One significant technique in image processing is morphological image operations, which include methods such as opening and closing. This research explores the application of the opening and closing methods in improving the quality of banana images. The Opening process effectively reduces noise and eliminates small, unwanted details, improving the clarity of the image. However, the Closing process presents some challenges, particularly in altering the natural texture of the banana and blurring fine lines. Careful adjustments are necessary to avoid reducing the visual quality of the image. The study begins with pre-processing steps such as image cleaning and contrast adjustment to enhance the image clarity. The Opening operation, using mathematical morphology and a structural element, removes unwanted small elements from the image, making fine lines and textures more visible for further analysis. The Closing operation, applied after Opening, fills small gaps and connects separated parts of the banana image, restoring the original structure and maintaining image continuity. The combined application of opening and closing methods significantly enhances the quality of banana images by improving clarity, preserving structural integrity, and optimizing overall visual appearance.*

Keywords: *banana image, closing method, image processing, image quality enhancement, opening method.*

Abstrak—*Salah satu teknik penting dalam pemrosesan citra adalah operasi morfologi, yang mencakup metode seperti opening dan closing. Penelitian ini mengeksplorasi penerapan metode opening dan closing dalam meningkatkan kualitas gambar pisang. Proses opening secara efektif mengurangi noise dan menghilangkan detail kecil yang tidak diinginkan, sehingga meningkatkan kejernihan gambar. Namun, proses closing memiliki beberapa tantangan, terutama dalam mengubah tekstur alami pisang dan menyebabkan garis-garis halus menjadi kabur. Penyesuaian yang cermat diperlukan agar kualitas visual gambar tidak berkurang. Penelitian ini dimulai dengan langkah pra-pemrosesan seperti pembersihan gambar dan penyesuaian kontras untuk meningkatkan kejernihan gambar. Operasi opening, dengan menggunakan morfologi matematis dan elemen struktural, menghilangkan elemen kecil yang tidak diinginkan dari gambar, membuat garis-garis halus dan tekstur lebih terlihat untuk analisis lebih lanjut. Operasi closing yang diterapkan setelah opening mengisi celah-celah kecil dan menghubungkan bagian-bagian gambar pisang yang terpisah, sehingga memulihkan struktur asli dan menjaga kontinuitas gambar. Penerapan gabungan metode opening dan closing secara signifikan meningkatkan kualitas gambar pisang dengan meningkatkan kejernihan, menjaga integritas struktural, dan mengoptimalkan penampilan visual keseluruhan.*

Kata Kunci*: citra buah pisang, metode closing, pengolahan citra, peningkatan kualitas citra, metode opening.*

INTRODUCTION

Digital image processing is a rapidly developing field within computer technology and engineering. One significant technique in image processing is morphological image operations, which include methods such as opening and closing. These methods play a crucial role in improving and refining imperfect images by filling in small holes and enhancing the contours or structures within an image. Opening is a combination of erosion and dilation operations, while closing is a combination of dilation and erosion, both widely used in image processing to enhance the shape of objects (Fitriyah & Wihandika, 2021). Image enhancement through closing and opening methods is also vital for various practical applications, including medical imaging (e.g., tumor detection), satellite image analysis for mapping, and pattern recognition in machine vision, where morphological methods are necessary to improve accuracy and precision in image analysis (Sumijan & Purnama, 2021).

The significance of closing and opening methods in image processing also relates to their ability to preserve essential characteristics of objects within the image (Trianto, Sinaga, Marzuki, & Qorni, 2022). Thus, image processing not only eliminates noise but also preserves crucial information (Situmorang, Hasibuan, & Siregar, 2022). Although they have distinct advantages, morphological methods like opening and closing also present limitations and challenges (Apridiansyah, Toyib, & Wijaya, 2022). Choosing the appropriate structural element (kernel) size and adjusting parameters can impact the final enhancement result (Sitinjak, 2020). For this reason, research continues to improve the effectiveness and efficiency of morphological methods in image processing. However, the opening and closing methods still have limitations in handling noise of a certain size and in preserving fine object details in an image. Additionally, these methods are often less effective under varying lighting conditions or when dealing with images with complex textures. Therefore, this study will compare their effectiveness with the latest techniques in enhancing the quality of banana images to identify a more optimal method for classification and further analysis.

With rapid technological advancements and the growing complexity of image processing, a deep understanding of morphological methods such as closing and opening is essential. Proper utilization of these methods not only enhances image quality but also supports the development of various applications that rely heavily on image processing technology (Arnita, Marpaung, Aulia, Suryani, & Nabila, 2022). Morphological operations are image processing techniques based on the shape of segments or regions within an image. Since they focus on the shape of objects, these operations are typically applied to binary images, including dilation, erosion, closing, and opening (Hou et al., 2021). Furthermore, morphological opening and closing operations are used to enhance the clarity of objects to be classified (Rumandan, Nuraini, Sadikin, & Rahmanto, 2022).

The theoretical foundation of morphological operations was introduced by Georges Matheron in the 1960s. His contributions laid the groundwork for subsequent developments in morphological image processing. Although Matheron did not specifically establish the opening and closing methods, his concepts serve as the basis for these enhancement techniques (Soedjono, 2019; Salvi, Acharya, Molinari, & Meiburger, 2021). The fundamental principles of morphological operations, including opening and closing, have been extensively discussed in image processing literature, such as in Gonzalez and Woods' Digital Image Processing (Kumar, Chakravarty, Gupta, Baig, & Albreem, 2022).

Morphological operations, including opening and closing, continue to evolve through ongoing research and advancements in digital image processing. Various experts an d researchers have contributed to refining these techniques for specific applications, such as medical imaging, satellite analysis, and pattern recognition (Trianto et al., 2022). These methods have been further adapted to enhance image clarity and facilitate object classification in complex environments.

This research aims to compare the image enhancement methods of opening and closing with state-of-the-art techniques to support the classification of ripe and unripe fruits. The classification process groups objects based on specific criteria related to their attributes (Khairullah & Putra, 2021). In this study, morphological image processing is applied to improve banana image quality by reducing background noise. Compared to standard techniques such as Gaussian filtering, opening and closing operations offer a computationally efficient approach to noise reduction. The results of this study are expected to contribute to automated quality inspection and sorting processes in the agricultural industry, providing a foundation for more accurate classification and quality assessment.

MATERIALS AND METHODS

This study applies morphological image processing techniques, specifically the opening and closing methods, to enhance the quality of banana images. The opening and closing methods are widely used for noise reduction, shape preservation, and feature enhancement in digital image processing. By utilizing these methods, this research aims to improve the clarity and structural integrity of banana images, making them more suitable for further analysis. Below, we describe the specific procedures and parameters used to achieve these enhancements.

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Image enhancement

Image enhancement is an important process in image processing that aims to improve the visual quality of an image. The main goal of image enhancement is to improve clarity, sharpness, contrast, and reduce noise or disturbances that can affect the overall image quality. Image enhancement methods can involve various techniques, ranging from simple ones like brightness and contrast adjustments to more sophisticated techniques like noise removal and detailed imaging (Supiyanto & Suparwati, 2021). One common technique used in image enhancement is brightness and contrast adjustment. By increasing brightness, an image that is too dark can become brighter and clearer, while increasing contrast can enhance the distinction between dark and bright areas in the image. This technique is commonly used to make images more visually appealing and easily understandable (Supiyanto & Suparwati, 2021).

Noise Removal

Noise removal is also an integral part of image enhancement. Noise is random disturbances that can blur details and reduce image sharpness. Various techniques like median filters or Gaussian filters are used to reduce or eliminate unwanted noise from the image, improving clarity and enhancing details in the image (Setyansyah, Siregar, & Khairani, 2021).

Smoothing technique

Furthermore, another technique commonly used in image enhancement is smoothing technique, which aims to reduce imperfectionsor rough lines in the image. Smoothing helps to reduce small details and blur intensity differences, which in turn can result in a smoother and more visually pleasing image (Sari, Maulita, & Ambarita, 2021).

Histogram

Grafik histogram is a visual representation of data distribution. Histograms are commonly used to show the frequency or occurrence distribution of data within a range. Here are the histogram results for image enhancement operations on a banana fruit using the opening and closing methods (Fitriyah & Wihandika, 2021).

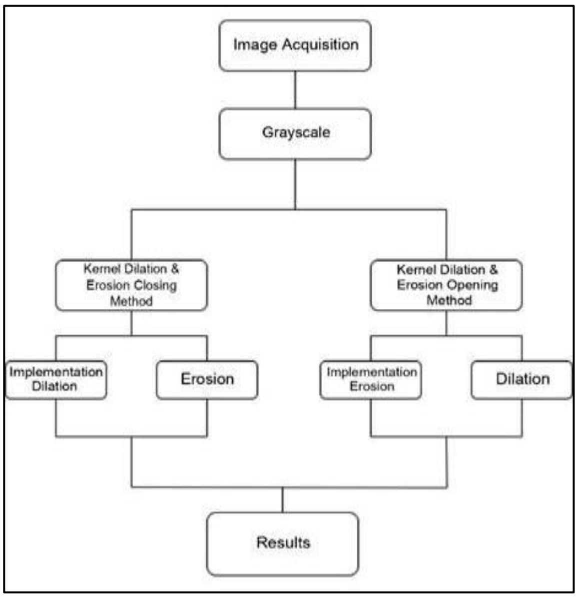
Detailed Imaging

Image detailing is one advanced technique in image enhancement that focuses on enhancing the small details in an image without adding unwanted noise. This method is highly useful in medical imaging, forensics, as well as in the fields of artificial intelligence and computer vision, where fine details often hold significant information value (Dijaya, 2023).

With advancing technology, image enhancement becomes increasingly important not only for more traditional applications like photography and computer graphics, but also in artificial intelligence, computer vision, pattern recognition, and various other industries where visual analysis is crucial. Innovation and development of image enhancement methods continue to be conducted to improve their quality and relevance in various fields (Arnita et al., 2022).

Image improvement flow diagram using the opening and closing method

Figure 1 presents the process of image enhancement using the opening and closing methods. The process begins with image acquisition, followed by grayscale conversion. Then, morphological operations (dilation and erosion) are applied to reduce noise and preserve key image features before producing the final result.



Source : (Trianto et al., 2022)

Figure 1. Image Enhancement Flow Diagram Using the Opening and Closing Method

1. Image Acquisition

The images taken from Kaggle.com were 10 images with an average size of 50 kb. Figure 2 shows an image of a banana, which is used in the image acquisition process.

Source : (Buyukkinaci, 2019)

Figure 2. Example of a Banana Used in the Image Acquisition Process

2. Grayscale
Grayscale is an image that has shades of gray. The use of grayscale images is because it requires minimal information to convey (Fitriyah & Wihandika, 2021).

Source : (Research Results, 2024)
Figure 3. Example of a Grayscale Image, Showing the Conversion of a Colored Image into Shades of Gray

Figure 3 illustrates the grayscale transformation, which is an essential preprocessing step in image processing, as it reduces computational complexity while preserving important object features.

3. Kernel erosion and dilation
Erosion and dilation kernels are concepts in image processing in the fields of image processing and computer vision (Fitriyah & Wihandika, 2021).

4. Application of erosion
The application of erosion is to combine images with structuring elements, which determine the size and shape of the erosion. The output of the erosion operation is a new image where the pixels in the original image are eroded or shrunk (Fitriyah & Wihandika, 2021).

5. Dilation
At each point in the image, dilation will examine the surrounding environment or area and replace the pixel value at that point with the maximum pixel value in that area (Fitriyah & Wihandika, 2021).

6. Kernel dilation and erosion
Dilation and erosion kernels are concepts in image processing in the fields of image processing and computer vision (Fitriyah & Wihandika, 2021).

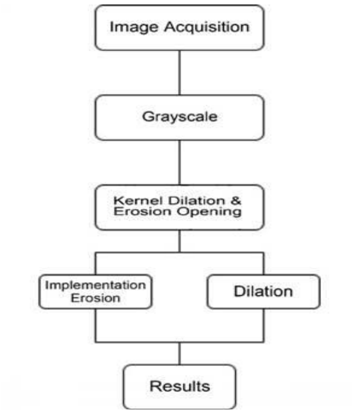
7. Application of dilation
The application of Dilation can be used to fill small gaps in objects in the image (Fitriyah & Wihandika, 2021).

8. Erosion
Erosion is used to separate objects that are close together, remove small details, or shrink objects (Fitriyah & Wihandika, 2021).

a. Opening Method
The operation of Opening can be defined as an erosion operation followed by a dilation operation. The equation for the Opening morphological operation is as follows:

$$A \circ B = (A \ominus B) \oplus B \quad (1)$$

Figure 4 presents the flow diagram of the Opening operation, consisting of several stages: image acquisition, grayscale conversion, kernel dilation & erosion application, and a final dilation step before obtaining the final result. By analyzing this diagram, we can better understand how the Opening operation functions in image processing:

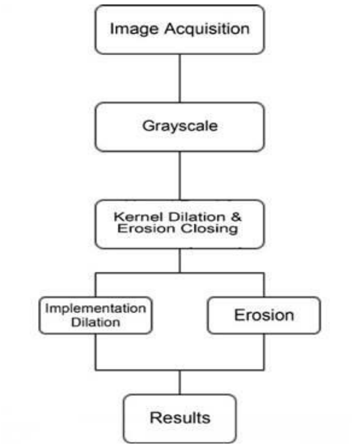


Source : (Trianto et al., 2022)
Figure 4. Flow Diagram of the Opening Method in Image Processing

b. Closing Method
The Closing operation, which is the inverse of the Opening operation, is defined as a dilation operation followed by an erosion operation. Here is the equation for the Closing operation:

$$A \cdot B = (A \oplus B) \ominus B \quad (2)$$

Based on the diagram below, which illustrates the process of the Closing operation, we can better understand the steps involved in this method:



Source : (Trianto et al., 2022)
Figure 5. Closing Method

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RESULTS AND DISCUSSION

Table 1 below presents a comparative analysis of banana images processed using morphological operations. The Original Image column displays the unprocessed banana images in full color, preserving details such as skin texture and banana tips, which reflect variations in color and texture.

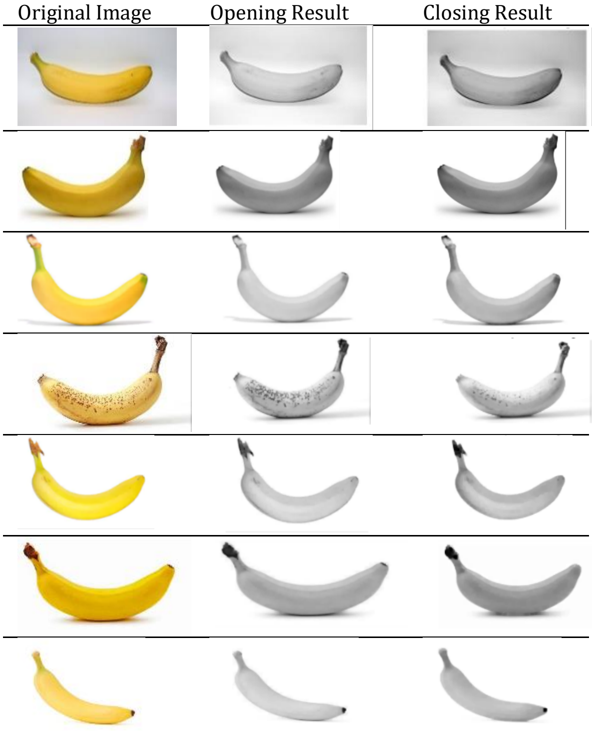
In the Opening Result column, the application of the morphological opening operation-comprising erosion followed by dilation-removes fine details and converts the image to grayscale. This process smooths the banana's structure, particularly along its edges, due to the effects of erosion and dilation, which eliminate small details.

Conversely, the Closing Result column, where dilation is applied before erosion, produces a grayscale image with a more solid banana structure. This method fills small gaps in the object and enhances the edges, creating a denser and clearer shape compared to the Opening result.

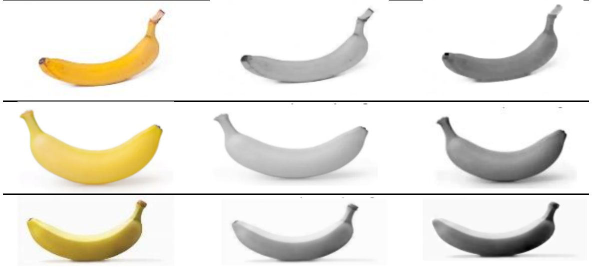
The key distinction between the two operations lies in their effects on image structure: Opening tends to remove small details both inside and outside the object, resulting in a smoother appearance, while Closing fills gaps and reinforces edges, producing a more solid and well-defined representation.

Table 1. Results on Banana Fruit Using opening and closing Methods

Original Image	Opening Result	Closing Result



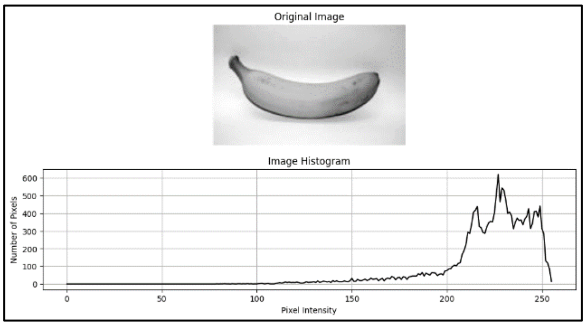
Original Image	Opening Result	Closing Result



Source : (Research Results, 2024)

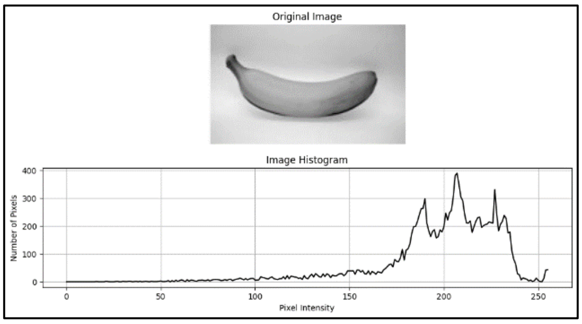
Histogram

In this study, histograms are used to analyze grayscale banana images, highlighting variations in light and dark regions that indicate differences in texture, ripeness, and overall image characteristics.



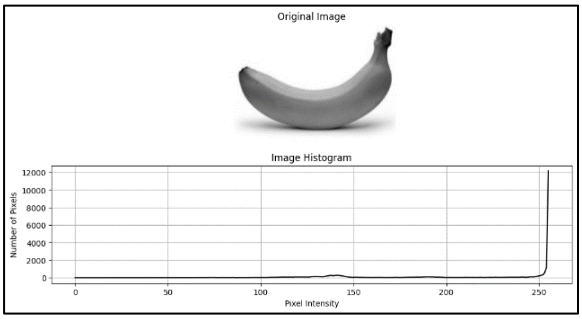
Source : (Research Results, 2024)
Figure 6. Histogram (Opening) of Sample A

Figure 6 represents the original grayscale banana image, while the histogram below displays the pixel intensity distribution. The histogram indicates the number of pixels for each intensity level, showing a higher concentration in the brighter regions, which corresponds to the lighter areas of the banana in the image. This analysis helps in understanding the contrast and brightness distribution within the image.



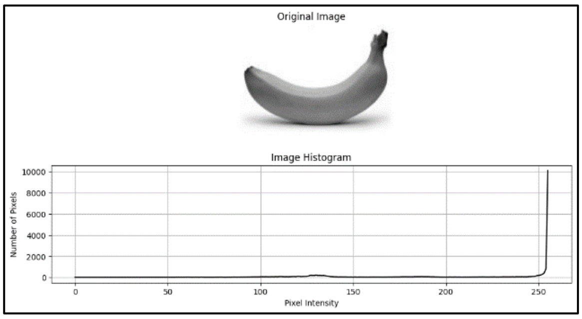
Source : (Research Results, 2024)
Figure 7. Histogram (Opening) of Sample B

Figure 7 shows the original grayscale banana, while the histogram below represents the pixel intensity distribution. The histogram reveals a higher concentration of pixel values in the brighter regions, indicating that most parts of the image are in the lighter grayscale range. This helps in analyzing the contrast and brightness levels of the image.



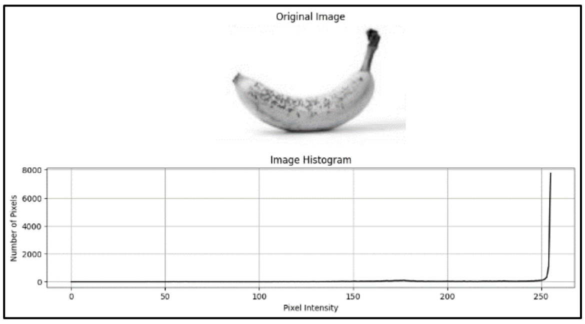
Source : (Research Results, 2024)
Figure 8. Histogram (Opening) of Sample C

The grayscale banana image in Figure 8 is accompanied by a histogram displaying its pixel intensity distribution. The histogram shows a significant peak at the highest intensity level, indicating that a large portion of the image consists of bright pixels, which suggests high contrast and well-lit areas.



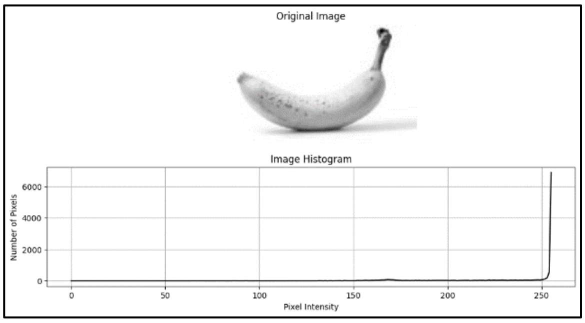
Source : (Research Results, 2024)
Figure 9. Histogram (Closing) of Sample A

The grayscale banana image is shown Figure 9, with its corresponding histogram below. The histogram indicates that most pixel intensities are concentrated at the higher end, suggesting that the image is predominantly bright with minimal dark regions.



Source : (Research Results, 2024)
Figure 10. Histogram (Closing) of Sample B

The grayscale banana image in Figure 10 exhibits visible dark spots on its surface, indicating ripeness or decay. The corresponding histogram shows a high concentration of pixel intensities at the brighter end, with some distribution in the lower intensity range, reflecting the presence of both bright and dark areas in the image.



Source : (Research Results, 2024)
Figure 11. Histogram (Closing) of Sample C

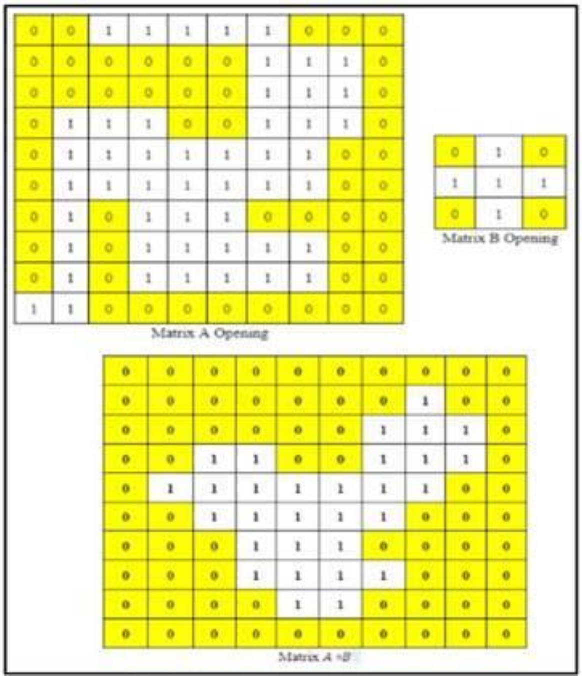
Based onf Figure 11, the grayscale image of the banana shows dark spots scattered across its surface, indicating ripeness. The histogram below reveals a high concentration of bright pixels near the upper intensity range, with a slight presence of lower-intensity pixels corresponding to the dark spots.

Confusion Matrix

A Confusion Matrix is a fundamental tool for evaluating the performance of a classification algorithm, offering a detailed breakdown of how well the model distinguishes between different classes. It comprises four key components: True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN). These values provide a basis for calculating essential performance metrics such as accuracy, precision, recall, and F1-score, which collectively help assess the model's effectiveness. By analyzing the Confusion Matrix, researchers can identify misclassifications, understand error distribution, and refine the model for improved classification performance.

1. Opening

Based on the opening matrix, to perform the Opening operation using functions available in the image processing toolbox, which combines erosion and dilation operations, here is an example.
Coding:
strElement = [1 1 1; 1 1 1; 1 1 1];
gearOpening = imdilate(imerode(gearBW, strElement), strElement); (Neto, 2024).

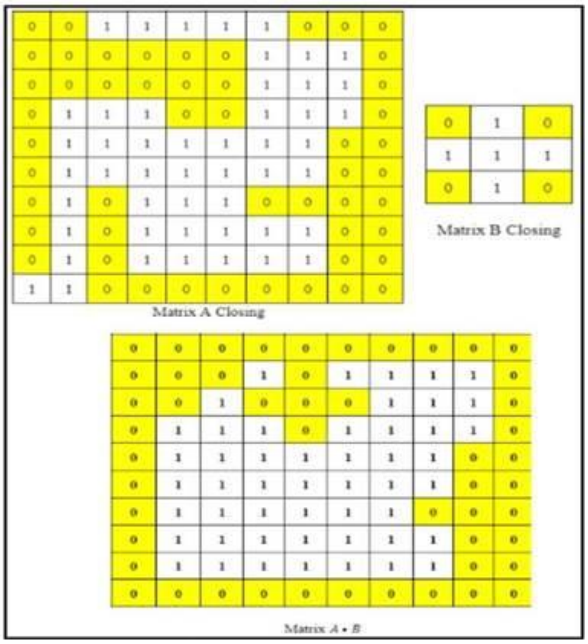


Source : (Research Results, 2024)
Figure 12. Opening Matrix

Figure 12 illustrates this process. The top-left matrix represents the original binary image (Matrix A), while the small matrix (Matrix B) is the structuring element. The result of erosion is displayed in the bottom matrix (Matrix A ⊖ B), where small protrusions and noise have been removed. The final dilation step restores the object's main structure while preventing unwanted artifacts from reappearing. This confirms that the Opening operation effectively enhances the image by refining shapes and eliminating minor noise.

2. Closing
The opposite of the Opening operation, the Closing operation is defined as a dilation operation followed by an erosion operation. So, based on the closing matrix, to perform the Closing operation using functions available in the image processing toolbox, which combines dilation and erosion operations, here is an example.
strElement = [1 1 1; 1 1 1; 1 1 1];
gearClosing = imdilate(imerode(gearBW, strElement), strElement); (Neto, 2024).

Figure 13 illustrates the process of the Closing operation, which is the inverse of the Opening operation. In this process, dilation is applied first, expanding the boundaries of objects and filling small gaps. This step is followed by erosion, which restores the object's shape while maintaining the filled gaps.
The top-left matrix represents the original binary image (Matrix A), where small gaps or breaks exist within the objects. The small matrix (Matrix B) is the structuring element used for dilation and erosion. The result of dilation (Matrix A ⊕ B) is shown in the bottom matrix, where the small holes within the object have been filled. The final erosion step refines the structure while preventing noise expansion.
This operation is particularly beneficial in connecting broken structures and filling small gaps, making it useful in various image processing applications such as character recognition and object segmentation.



Source : (Research Results, 2024)
Figure 13. Closing Matrix

CONCLUSION

This study successfully enhanced the banana fruit image using opening and closing operations, as indicated by improved PSNR and SSIM values, which reflect increased clarity and structural integrity. The opening operation effectively reduced unwanted noise and small details, enabling a clearer view of fine lines and textures. However, the closing operation occasionally blurred natural textures, highlighting the need for precise parameter adjustments to balance noise reduction with detail preservation. Future research could explore alternative morphological structures or refined parameters to further enhance image quality for agricultural applications.

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