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Comparison Analysis of HSV Method, CNN Algorithm, and SVM Algorithm in Detecting the Ripeness of Mangosteen Fruit Images

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ABSTRACT
Mangosteen contains a substance known as Xanthone, a phytochemical compound with the distinctive red component in mangosteen that is known for its properties as an anticancer, antibacterial, and anti-inflammatory agent. Additionally, Xanthone has the potential to strengthen the immune system, promote overall health, support mental well-being, maintain microbial balance in the body, and improve joint flexibility. The mangosteen fruit is consumable when it reaches maturity, displaying a dark purplish-black color. Besides the edible part of the fruit, the peel also possesses remarkable medicinal properties. To detect whether the fruit is ripe or not, this research employs image processing techniques. The study utilizes the Hue, Saturation, and Value (HSV) color space method, Convolutional Neural Network (CNN) algorithm, and Support Vector Machine (SVM) algorithm. These methods and algorithms are chosen for their relatively high accuracy levels. The dataset used in this research is obtained from mangosteen datasets available on Kaggle. The results of this study indicate that the HSV method achieved an accuracy of 86.6%, SVM achieved an accuracy of 87%, and CNN achieved an accuracy of 91.25%. From the achieved accuracies, it is evident that the CNN algorithm yields higher accuracy compared to the others.

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1. INTRODUCTION

Mangosteen is one of the plants from the Guttiferae family, native to Southeast Asia [1]. Mangosteen fruit has many benefits, especially in its peel. The peel of mangosteen is often used as a remedy for health, as it is rich in antioxidants such as xanthones and anthocyanins [2]. In addition to its medicinal uses, mangosteen peel has been proven to moisturize the lips [3].

Mangosteen fruit is typically harvested after 104 days from the blooming of mangosteen flowers. At the age of 104 days, the fruit is not fully ripe, appearing only slightly purple. To be consumed, mangosteen fruit must be stored until it turns completely black [4]. To identify ripe and unripe fruit, computer researchers have conducted numerous studies, including the use of digital image processing [5]. Digital image processing explores how an image is formed, processed, and analyzed to produce information understandable by humans [6].

The following is a study that detects fruit ripeness using digital images. Research [7] detects ripeness based on the texture of melon using a Gray Level Co-occurrence Matrix (GLCM) feature extraction algorithm and Support Vector Machine (SVM). The accuracy achieved is 80%. Another study [8] detects the ripeness of avocados by weighting the RGB values. The result is a 90% detection rate for ripe avocados with a 10% error. Subsequently, [9] detects ripeness in oranges using the Hue, Saturation, and Value (HSV) color space transformation. The analysis of 10 oranges yields Hue values between 0.627 and 8.991. Then, [10] detects ripeness in tomatoes using the HIS color space transformation, achieving an accuracy of 94.28%. In the last study [11], mangosteen detection using HSV is successful.

Several studies have shown a dependency on lighting conditions. When tested under low light, detection errors frequently occur. Therefore, this research aims to detect mangosteen ripeness using various image datasets of mangosteens obtained from Kaggle. The extensive use of datasets is expected to facilitate mangosteen detection from multiple perspectives. This study also employs several methods and algorithms to determine the effectiveness of mangosteen detection. The research continues to use the HSV color space transformation. HSV, which stands for Hue Saturation Value, is a color model derived from the Red Green Blue (RGB) model. Consequently, converting RGB to HSV is necessary to obtain HSV colors [12]. HSV is one way to define colors based on the color wheel [13]. The research begins with input from the collected dataset, followed by calculating the RGB values. These RGB values are then converted to HSV. Subsequently, Euclidean distance calculations are performed, and by summarizing the closest distances, the classification of mangosteen ripeness based on color using the HSV color space transformation is completed.

In addition to using HSV, this study will also compare results with the Convolutional Neural Network (CNN) algorithm. CNN is a neural network commonly used for image data [14]. This algorithm can be employed to detect and recognize objects in images [15]. It is often chosen for its accuracy in object detection [16]. Previous studies have used CNN to detect diseases in tomato leaf images, achieving accuracies between 80% and 94% [17]. CNN has also been used to detect mango ripeness with an accuracy of 97.6% [18]. Furthermore, detecting fresh and rotten fruit resulted in an accuracy of 91.65% [19]. Based on the success of these studies, the current research employs CNN to detect mangosteen ripeness. Additionally, the SVM algorithm is used for mangosteen image detection, as SVM has been widely utilized for fruit ripeness detection, achieving high accuracies in previous studies. For instance, SVM was used to detect melon ripeness with an accuracy of 80% [20], and another study [21] achieved a ripeness detection accuracy of 91.1% for tomatoes. The success of these prior studies forms the basis for the comparative analysis conducted in this research to detect mangosteen ripeness.

2. RESEARCH METHOD

This research employs a methodology to streamline the research process, as depicted in Figure 1.

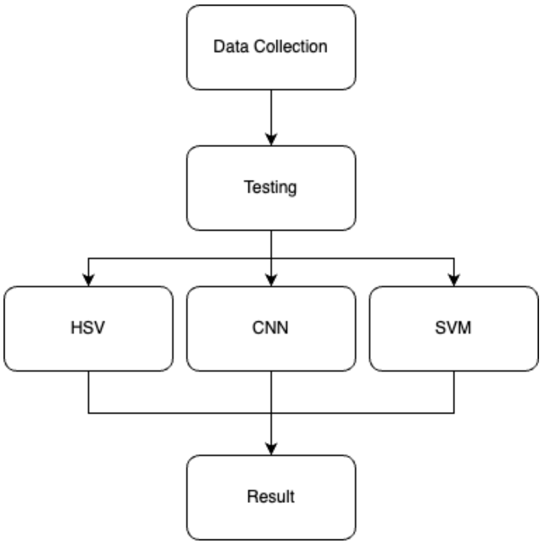


Figure 1. Research Methodology

2.1. Data Collection

The dataset for this study consists of various images of mangosteen collected from Kaggle. The total number of records to be tested is 1105, categorized into two groups: unripe and ripe mangosteen. The images are taken from multiple perspectives to enhance testing accuracy.

2.2. Testing

This study compares three methods or algorithms CNN, SVM, and HSV. Figure 2 illustrates the workflow for detecting mangosteen ripeness.

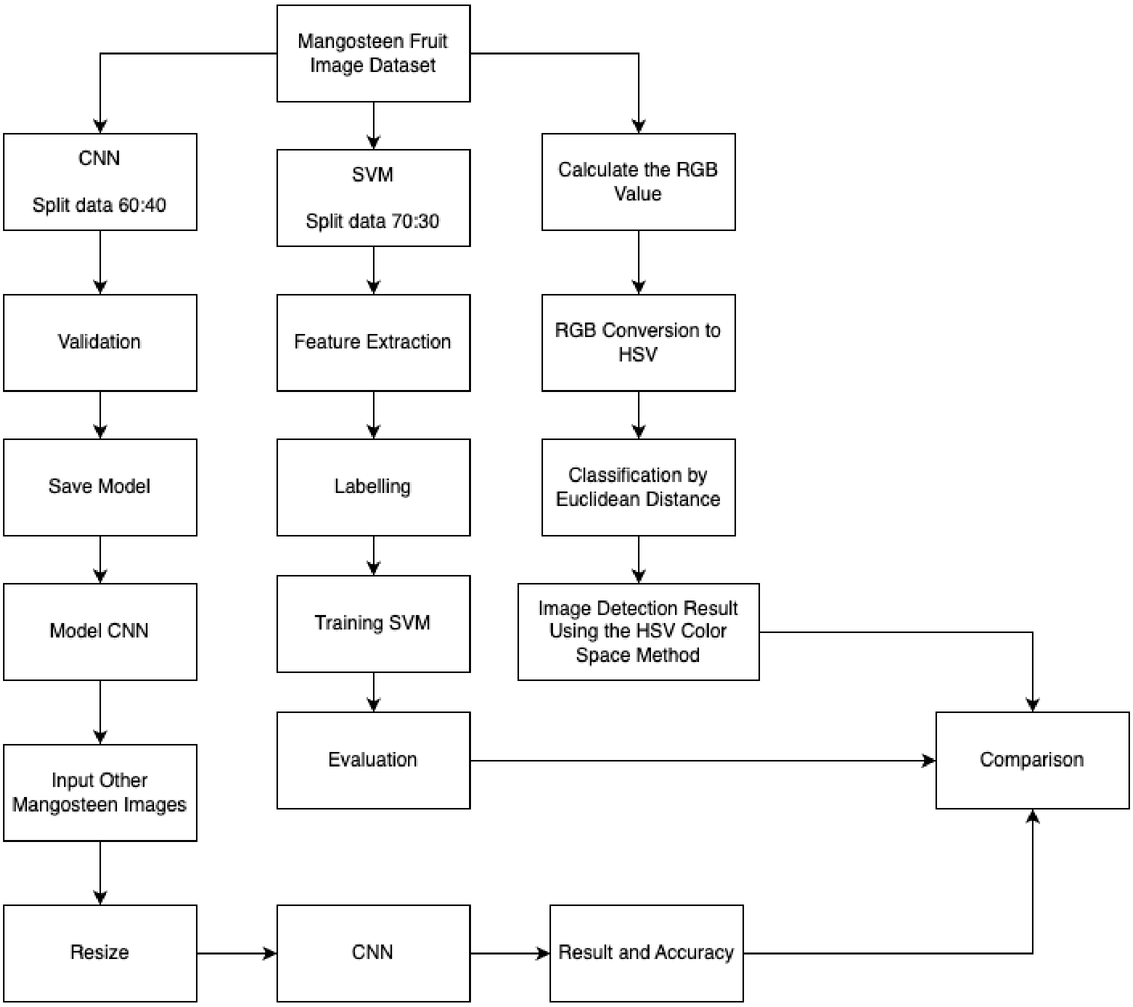


Figure 2. Image Detection Flow

The Convolutional Neural Network (CNN) approach, the process begins by splitting the mangosteen image dataset into two parts: 60% for training and 40% for validation. The CNN model is trained using the training data and evaluated with the validation data to monitor its performance. Once training is complete, and the model shows satisfactory performance, it is saved. New mangosteen images are then inputted into the system, resized to meet the model's requirements, and processed by the CNN. The model analyzes the images to detect and classify the ripeness of the mangosteen based on the visual features learned during training.

For the Support Vector Machine (SVM) approach, the process starts with splitting the mangosteen image dataset into two parts: 70% for training and 30% for testing. Important features such as texture, color, or shape of the mangosteen are extracted from these images. Each image is then labeled according to its ripeness level. Using this labeled data, the SVM model is trained to learn the patterns that distinguish ripeness levels based on the extracted features. After training, the model is evaluated using the testing data to assess its performance in detecting mangosteen ripeness.

The HSV approach begins by calculating the Red, Green, Blue (RGB) values of the mangosteen images. These RGB values are then converted to Hue, Saturation, Value (HSV) values, which are more suitable for color analysis as they closely match human color perception. Classification is performed using the Euclidean distance method, where the distance between the HSV values of the test images and the known HSV values of samples with identified ripeness levels is calculated. Based on the closest distance, the ripeness of the mangosteen is classified. The ripeness detection result is determined based on the skin color of the mangosteen analyzed using the HSV color space method.

The accuracy of these three methods or algorithms is then compared to determine the most effective approach for detecting mangosteen ripeness.

3. RESULTS AND ANALYSIS

The data analysis for mangosteen fruit ripeness detection based on color features of the peel image using the HSV color space transformation method involves gathering a dataset and seeking information for the analysis of data collection needs. To obtain identified data, a testing system is produced to determine the ripeness of mangosteen fruit based on color features of its peel image, and thus, it is necessary to acquire a dataset of mangosteen fruit.

The analysis of requirements comprises interaction prerequisites, input requirements, and output requirements. Process requirement analysis explains how the system will function, the cycle used, starting from the flow of information handled by the system until it becomes the final output (final presentation). The implementation in MATLAB uses the HSV color space for detecting the ripeness of mangosteen fruit in MATLAB 2020b. The program involves several stages, particularly in inputting mangosteen fruit images.

1. Extraction of mangosteen fruit images using the HSV color space.
2. Detection of mangosteen fruit type through Euclidean distance calculation.
3. Results of image detection using the HSV color space.

The implementation of the HSV method is done to find the values of Hue, Saturation, and Value in the RGB image [22]. In the manual HSV calculation process for determining the level of mangosteen fruit ripeness with ripeness detection, the stages include mature and raw. Next is the extraction of RGB images into HSV images. In the mangosteen fruit ripeness detection stage, the training and testing processes are carried out. The training process involves extracting the entire mangosteen image using HSV and storing it in the dataset. Meanwhile, the testing process involves testing the ripeness detection of mangosteen fruit with input fruit images. After obtaining the RGB values for each image, the next step is to convert the RGB values of mangosteen images A, B, and C into HSV values. The HSV formula used is as follows [23]:

$$H = \left(\frac{3(G-B)}{(R-G)+(R-B)}\right)$$

$$S = 1 - \frac{\min(R,G,B)}{V} \tag{1}$$

$$V = \frac{R+G+B}{3}$$

Based on the formula above, it can be explained that the first step is to find the H value, then determine the V value to obtain the S value. The HSV values from mangosteen images are then stored in a database for testing detection. This database is then used as a reference in the training of other mangosteen fruits. Figure 3 represents the initial display of image detection using HSV.

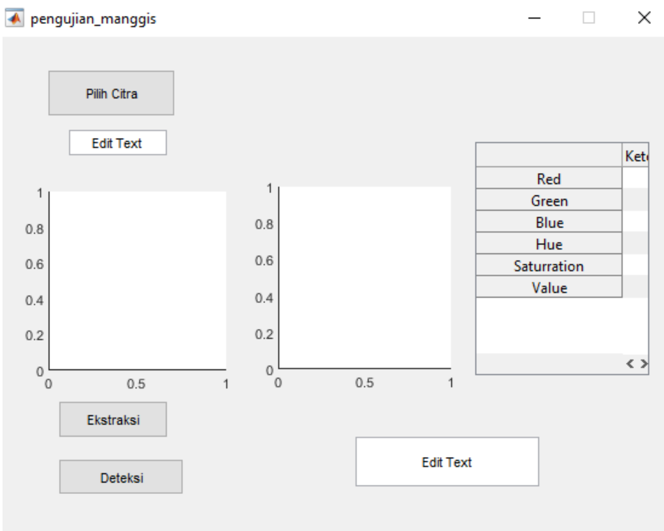
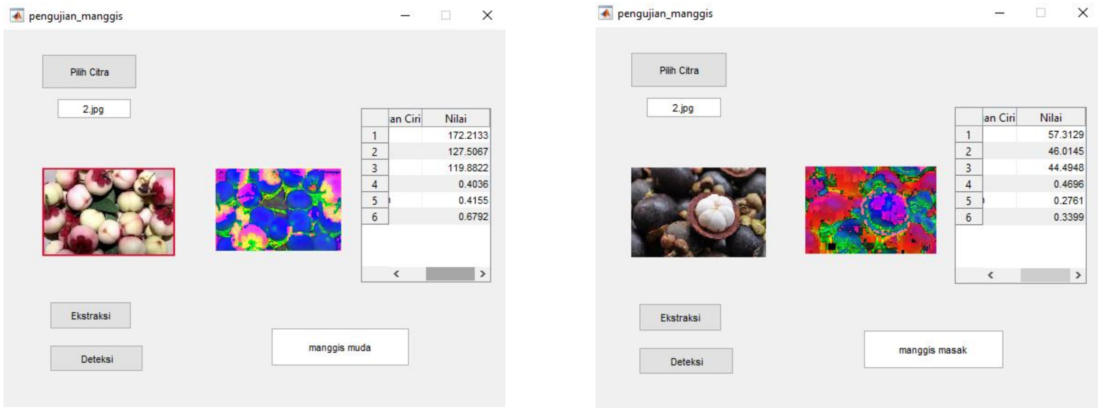


Figure 3. Initial Appearance in Detecting Mangosteen Fruit using HSV

The testing phase is conducted individually and randomly on freshly harvested mangosteen fruits. To initiate the ripeness detection process, one can start by selecting a mangosteen image by pressing the "Select Image" button, which will display a menu. After choosing the mangosteen image to be analyzed for ripeness, the system can read the image's name. Next, to commence the ripeness detection process of the mangosteen image, the first step is to extract the image by obtaining the HSV values. This can be accomplished by pressing the "Extraction" button. Subsequently, the ripeness detection of the mangosteen fruit image is performed by pressing the "Detection" button, displaying the results as shown in Figure 4.



(4a) (4b)

Figure 4. Detection of Mangosteen Fruit Using HSV Color Space Transformation

Based on Figure 4, the detection process has been successfully implemented in the application system. With the test image of the mangosteen fruit, it was accurately detected with the ripeness levels "Young Mangosteen" and "Ripe Mangosteen," demonstrating the system's accurate detection. Subsequently, the accuracy level is calculated based on the test results from mangosteen images taken from various datasets. From the accuracy test results, an accuracy value of 86.6% is obtained for the ripeness detection process using the HSV color space transformation. The next step is to conduct testing with CNN.

In the first step, files are extracted, and the number of ripe and young mangosteens is displayed. After extraction, Figure 5 represents an example dataset used in the study using CNN.

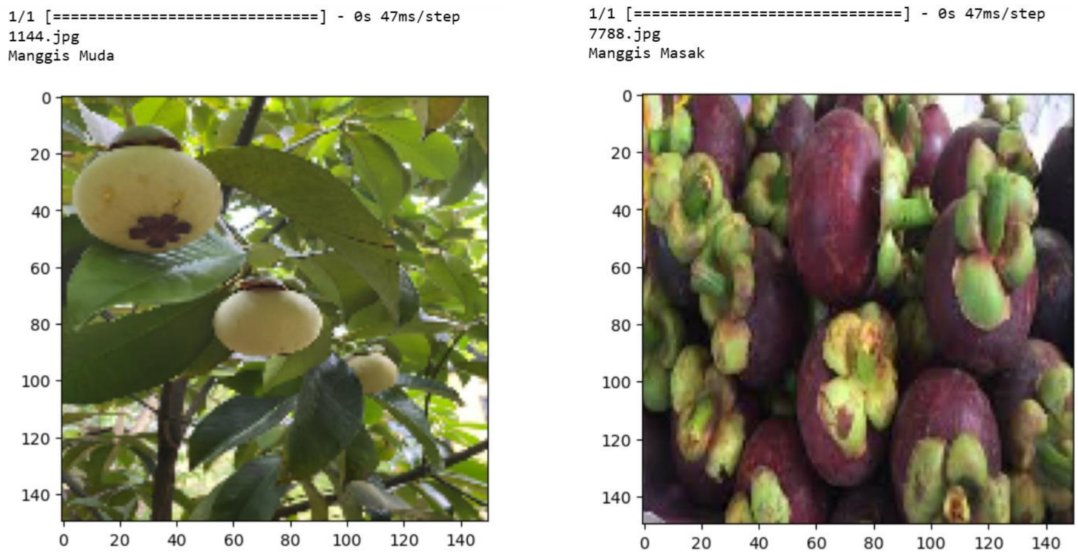
Figure 5. Dataset mangosteen Fruit

The next step is to perform image preprocessing. Image preprocessing involves normalizing the data, applying a scenario of rotating the image up to 30 degrees, implementing a scenario of elevating the image by 0.2 of its original size, applying a scenario of horizontally flipping the image, implementing a scenario of zooming the image by 0.2, applying a scenario of cropping the image by 0.2 of its original size, filling empty pixels with the nearest pixel value, and splitting the data into 60% for training and 40% for validation. To enhance the CNN results, this study uses compilation with the Adam optimizer. The CNN is then trained with 20 computation epochs. In the 20th epoch, the model achieves an accuracy of 91.25%, as observed in Table 1.

Table 1. Epoch Comparison Algorithm CNN

Epoch	Loss	Accuracy	Val Loss	Val Accuracy
1	68,81%	50,83%	67,61%	50,00%
2	69,28%	58,33%	64,13%	72,50%
3	62,36%	69,17%	57,15%	76,25%
4	51,00%	77,50%	52,73%	76,25%
5	43,35%	79,17%	43,53%	80,00%
6	37,73%	82,50%	30,16%	90,00%
7	23,83%	91,67%	28,93%	88,75%
8	19,57%	95,00%	19,63%	95,00%
9	18,11%	94,17%	20,46%	93,75%
10	20,90%	95,00%	36,87%	85,00%
11	27,00%	88,33%	21,65%	90,00%
12	16,54%	95,00%	26,80%	90,00%
13	16,72%	95,00%	19,93%	92,50%
14	16,94%	93,33%	25,69%	90,00%
15	15,64%	95,83%	19,80%	91,25%
16	18,32%	91,67%	29,28%	90,00%
17	21,01%	91,67%	28,92%	87,50%
18	23,16%	92,50%	26,83%	91,25%
19	15,83%	95,00%	21,82%	91,25%
20	16,09%	95,83%	25,73%	91,25%

After the training process, additional images are inputted. All input images are resized to 150x150 pixels, serving as data classes for classification. Figure 6 represents the detection results obtained using CNN.



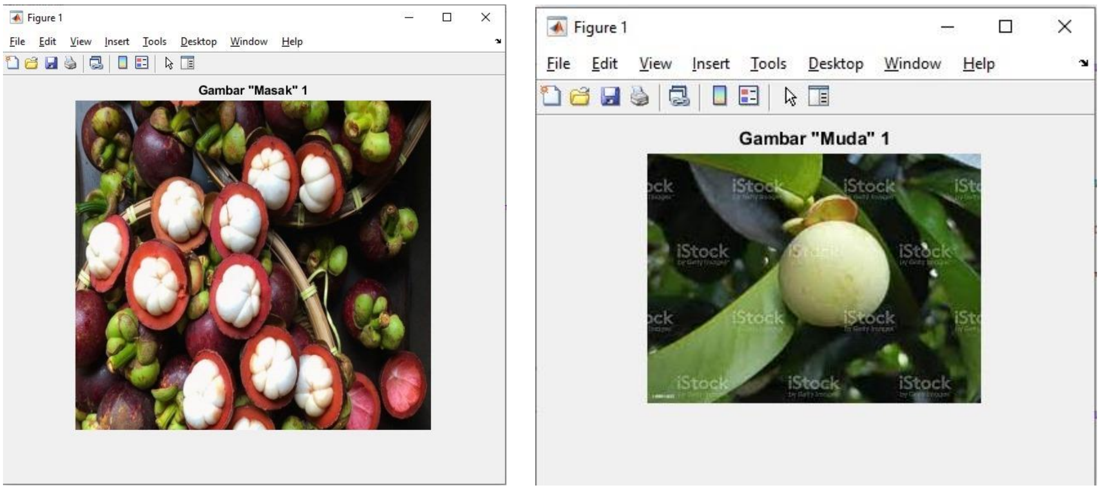
(6a) (6b)

Figure 6. Detection Result with The CNN Algorithm

After the detection process using HSV and CNN, the next step is to perform detection using SVM. SVM is a reliable method for solving data classification problems [24]. The SVM model processes data into training and testing sets. The training data is utilized to form the SVM model, and the values for its free parameters are selected from the initial dataset [25]. Subsequently, the generated SVM model is used to classify the testing data [26].

The SVM testing in this research involves splitting the data in a 70:30 ratio, and the accuracy result obtained by SVM in detecting mangosteen fruit is 87%. Figure 7 displays the detection results using SVM in MATLAB 2020b.

Based on this conducted research, there are differences compared to previous studies. The dataset used in this research includes a variety of images, such as mangosteen fruits still on the tree, a cluster of newly harvested mangosteen fruits, opened mangosteen fruits, and so on. In contrast, other studies utilized only a single image taken from various perspectives [27]. Furthermore, this research achieves a relatively high accuracy compared to previous studies. The accuracy obtained from the HSV color space transformation is 86.6%, which is higher than the 80% reported in a previous study [28]. This means that this research has a 6% higher accuracy than the earlier study.



(7a) (7b)

Figure 6. Detection Result with The SVM Algorithm

Moreover, the use of the CNN algorithm also results in a high accuracy of 91.25%, surpassing the accuracy achieved using HSV. This is notably higher than some studies utilizing the CNN algorithm. For example, in detecting ripe bananas, a study [29] obtained an accuracy of only 78%, and another study [30] achieved an average accuracy of 83.33% in detecting the ripeness of pineapples. In terms of the SVM algorithm, this research also attains a relatively high accuracy, although it is still below the CNN algorithm, with a value of 87%. When compared to other studies, this research still outperforms previous research. For instance, in detecting the ripeness of tomatoes, a study [31] achieved an accuracy of only 77.84%. Table 2 presents a comparison of the methods and algorithms used in the research for the detection of mangosteen fruit ripeness.

Table 2. Acuuracy Comparison

HSV Method	CNN Algorithm	SVM Algorithm
86,6%	91,25%	87%

4. CONCLUSION

Based on the findings discussed, it is evident that the dataset used in this study differs from several previous studies. This testing was conducted following the same procedure, which involved inputting the entire dataset of mangosteen images. Additionally, this study achieved relatively higher accuracy compared to previous research. In detecting mangosteen ripeness, the HSV method reached an accuracy of 86.6%. Furthermore, the use of the Support Vector Machine (SVM) algorithm in this study resulted in an increased accuracy of 87% compared to HSV. Besides HSV and SVM, this study employed a deep learning approach using the Convolutional Neural Network (CNN) algorithm, which achieved the highest accuracy of 91.25%.

However, this research has limitations, and further studies are necessary. The study relies on single methods and algorithms for detecting mangosteen fruit ripeness. Future research is expected to explore alternative methods to enhance the accuracy achieved. Additionally, the study only employs data with images of clusters of ripe and young mangosteen fruits. Future research is encouraged to detect the ripeness of mangosteen fruit in images containing a mix of ripe and young fruits.

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