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Exploring Classification, Size, and Quality of Mangifera Indica L. Through Image Processing and AI Techniques

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Abstract. This paper introduces methods for efficiently classifying mangoes intended for export, a market valued at approximately 4,500 million baht annually. The classification process is divided into two primary components: size categorization and quality assessment. The first phase involves categorizing mango sizes into four distinct categories (M, 1L, 2L, 3L), while the second phase focuses on assessing mango quality, particularly detecting anthracnose—a prevalent disease affecting mangoes. This detection is achieved through image processing techniques, where images are converted into binary representations and analyzed using both Artificial Neural Networks (ANNs) and Convolutional Neural Networks (CNNs). Comparative analysis reveals that CNN outperforms ANN in size classification, achieving a remarkable train accuracy of 99.16% and a test accuracy of 88.0%. Furthermore, in quality classification, CNN demonstrates a train accuracy of 91.0% and a test accuracy of 88.0%. These findings underscore the effectiveness of CNN techniques in accurately classifying mangoes for export, thereby facilitating improved quality control and market competitiveness.

Keywords. ANN, CNN, image processing, mango sorting

1. Introduction

Mangoes (Mangifera indica), belonging to the Anacardiaceous family, are native to South Asia and have gained widespread cultivation in tropical and subtropical regions globally. Renowned for their delectably sweet, occasionally tangy flavor and rich nutritional composition, mangoes are esteemed worldwide. With substantial levels of vitamins, A and C, dietary fiber, and diverse antioxidants, mangoes offer significant health benefits, warranting further exploration of their bioactive compounds [1]. Thailand's mango industry holds considerable economic significance, contributing to both domestic and international markets. Mango cultivation sustains rural farmers and bolsters regional food security, while a substantial portion of the harvest undergoes processing into value-added products such as dried mango. At the international level,

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Thailand stands out as a prominent exporter of both fresh and processed mangoes, with annual export values surpassing 1 billion Baht [2]. Key export destinations encompass China, Japan, South Korea, and other Southeast Asian nations. To facilitate international trade and adhere to stringent quality standards, mangoes undergo sizing protocols before exportation. These protocols typically employ weight-based grading, physical measurements (such as circumference or length), or a combination thereof to categorize mangoes into standardized size classifications.

Machine vision equips computers with the capability to perceive and interpret visual data from the real world [3]. Complementarily, machine learning empowers computers to learn and enhance their performance autonomously, discerning patterns and making data-driven predictions without explicit instructions [4]. And has pioneered a vision system for mango sorting, leveraging 2D and 3D feature analysis. This approach not only achieves accuracy comparable to human sorting but also promises increased efficiency. Deep learning (DL) is reshaping fields like healthcare, as exemplified by Suzuki, and colleagues who utilize DL and activity recognition (AR) for automating the assessment of gross motor skills in children [5]. And has pioneered a vision system for mango sorting, leveraging 2D and 3D feature analysis. Their system evaluates size, volume, and surface area from multiple images, employing a neural network for mango classification by Chalidabhongse and colleagues [6]. Moreover, research in fault detection and classification (FDC) by analyzing mount head surface pixels illustrates proactive fault detection using an Artificial Neural Network (ANN) model, reducing machine downtime, and enhancing production reliability. [7]. Additionally, the development of a portable fruit grading machine using computer vision for small-scale agriculture by Hadha and colleagues captures video images from a webcam and analyze them to categorize fruit quality according to grade [8]. There is also research that aims to develop a smart mango classification system using image processing and artificial intelligence to automate the sorting process, reduce labor costs, and improve productivity in the mango industry [9]. This study showcases the utilization of artificial intelligence (AI) coupled with image processing to construct a model for the precise classification of mangoes into acceptable and defective categories. Moreover, the model endeavors to establish a system adept at sorting mangoes based on size specifications suitable for export and international trade. Employing two distinct types of AI—Artificial Neural Networks (ANNs) and Convolutional Neural Networks (CNNs)—the proposed model is thoroughly examined in terms of image selection for AI training, model development procedures, model functionalities, and system performance evaluation.

2. Method and materials

For the study on classifying mango categories (size and quality) for export, images of mangoes were captured using a webcam under controlled lighting conditions. Two lighting conditions. The images were then augmented by adjusting brightness by ± 5%. The Binary Algorithm was used for image processing, and the resulting images were used as datasets. The datasets were divided into three parts: Train 70% Test 15% and Validation 15% with additional Unseen data for model testing. The experiment was divided into two sections. Section 1 involved classifying mango sizes as M, 1L, 2L, and 3L using Artificial Neural Network (ANN) and Convolutional Neural Network (CNN) models. Section 2 involved mango quality assessment. The Architecture method is shown in Figure 1.

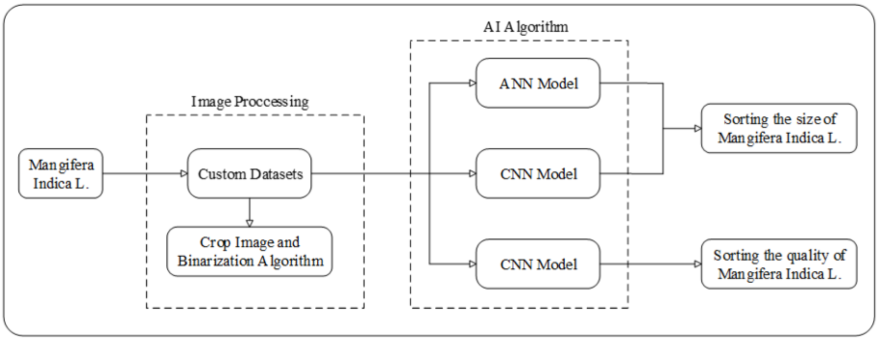

Figure 1. Architecture method.

2.1. Mangifera Indica L.

Mangos are the top fruit exported by Thailand. The ripe fruit is golden yellow, has a sweet aroma, and is called this type of mango "Nam Dok Mai Mango". The size for export will be divided by weight. As shown in Table 1. Quality control is therefore important. And anthracnose, which causes black spots on the mango skin. which affects the quality of exports shown in Figure 2.

Table 1. Table of mango size sorting by weight.

Size	Weight (grams)
M	225 – 249
1L	330 – 379
2L	380 – 449
3L	More than 450

(A)  (B)  (C) 

Figure 2. (A) Mangifera Indica L. (Nam Dok Mai Mango) (B) Mango for export (C) Anthracnose disease in mango.

2.2. Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is a computer model that simulates the workings of the human nervous system. The model architecture for mango size classification consists of 4 convolutional layers and 1 fully connected layer. ReLU is used as the activation function for the convolutional layers, and the fully connected layer uses Softmax activation function. Dropout is used to reduce overfitting. The hyperparameters used for training the model learning rate of 0.001, the structure model is shown in Figure 3.

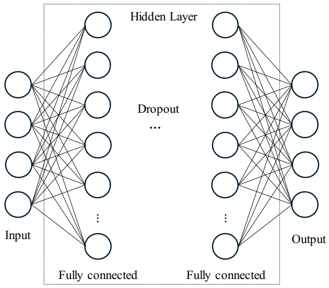

Figure 3. The structure ANN model.

2.3. Convolutional Neural Network (CNN)

Convolutional Neural Network (CNN) efficiently extracts main features from images using preprocessed image data and trained models over an appropriate period. For mango size separation and quality classification, the model employs a structure with 5 convolutional and 2 fully connected layers, along with Dropout to address overfitting. ReLU serves as the activation function, with SoftMax used in the output layer. The hyperparameters used for training the model learning rate of 0.001, the structure model is shown in Figure 4.

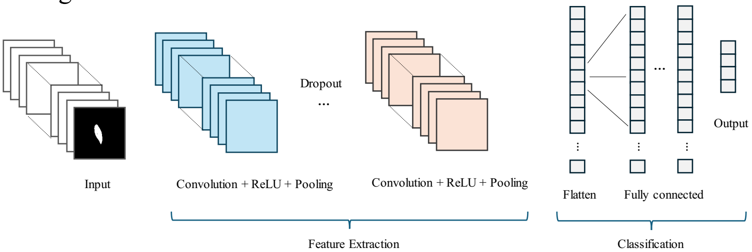

Figure 4. The structure CNN model.

2.4. Data acquisition

• Experimental setup

To collect the Dataset images, images were taken with a test set that was a conveyor for conveying fruit. A webcam camera was installed for taking photos, using a Logitech Brio camera, with the camera set at 55.5 centimeters from the floor of the conveyor. There are 2 stages of lighting control while taking photos. By adjusting from the Dimmable light bulb set and measuring the brightness with a Lux meter, where range 1 is 430-450 lux and range 2 is 1000-1020 lux. Shown in Figure 5.

(A) (B)

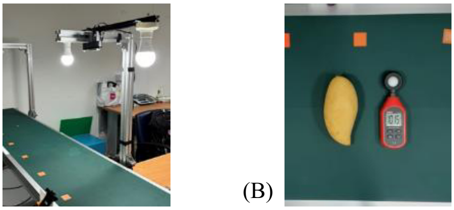

Figure 5. (A) Experimental setup (B) Lux meter.

• Image processing

After taking a photo of mango for Datasets, the image will be cut out in the edge of the Conveyer from the original size of 640 x 480 pixels, reduced to 620 x 300 pixels. Then a Binary Algorithm will be used to convert the image into two colors, white and black, to perform processing for detecting pixels in areas where objects are encountered. The example dataset is shown in Figure 6.

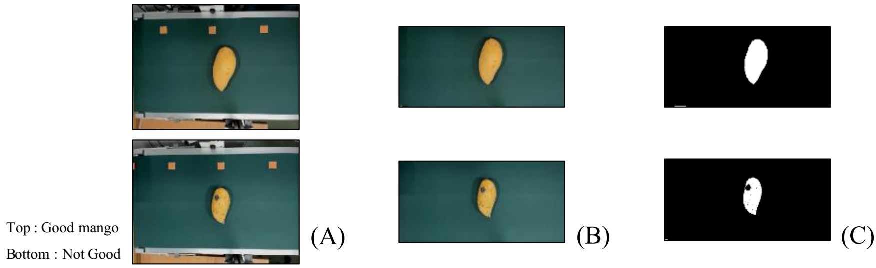

Figure 6. (A) Image capturing 640 x 480 pixels (B) Crop Image 620 x 300 pixels (C) Binary algorithm.

• Datasets

Dividing the data into training and testing sets, with 70% for training, 15% for testing, and 15% for validation. Adjust the lighting intensity by ± 5% to increase the number of image data (Data Augmentation) Then, test the model with unseen data, as shown in Tables 2 and 3.

Table 2. The number of datasets for training and testing mango size sorting.

Size	Datasets			
	Train	**Test**	**Validation**	**Unseen data**
M	150	30	30	10
1L	150	30	30	10
2L	150	30	30	10
3L	150	30	30	10
Summary	600	120	120	40

Table 3. The number of datasets for training and testing the quality of mango.

Type of Mango	Datasets			
	Train	**Test**	**Validation**	**Unseen data**
Good Mango	176	38	38	20
Not Good Mango	176	38	38	20
Summary	352	76	76	40

3. Experimental and results

In the experiment, the dataset is divided into two parts. Section 1 involves classifying mango sizes as M, 1L, 2L, and 3L using ANN and CNN models, and Section 2 involves detecting mango quality (Anthracnose disease) using the CNN model.

3.1. Classifying mango sizes as M, 1L, 2L, and 3L

To classify mango sizes into M, 1L, 2L, and 3L using ANN and CNN, the same dataset was used for training and unseen data. The results are shown in the confusion matrices in Figures 7 and 8.

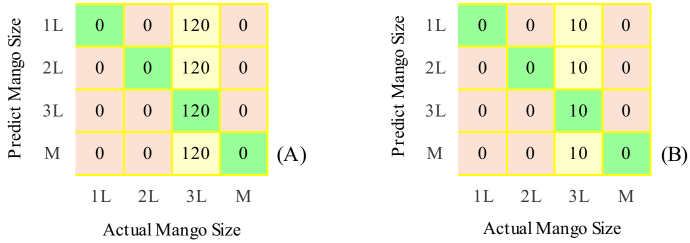

Figure 7. (A) Confusion Matrix Training ANN model. (B) Confusion Matrix Testing ANN model.

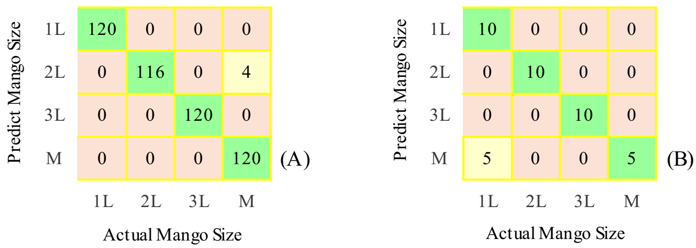

Figure 8. (A) Confusion Matrix Training CNN model. (B) Confusion Matrix Testing CNN model.

The results from training with ANN and CNN show that CNN is more accurate. The Confusion matrix provides an assessment of classification performance, including the number of samples classified correctly and incorrectly. The Train Accuracy of ANN is 25.0%, with a Test Accuracy of 25.0%. On the other hand, the Train Accuracy of CNN is 99.16%, with a Test Accuracy of 88.0%.

3.2. Detecting mango quality

When training with CNN to inspect or classify mangoes as good or not good based on the presence of anthracnose disease, which manifests as black spots on the mango skin, making them unsuitable for export. The results are presented in the confusion matrix in Figure 9.

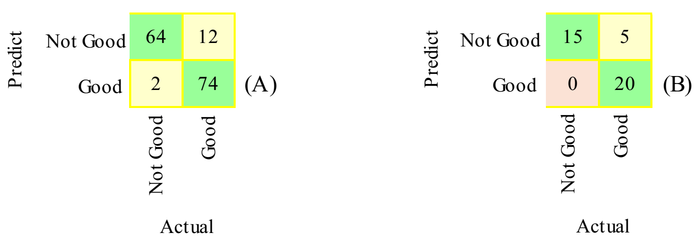

Figure 9. (A) Confusion Matrix Training CNN model. (B) Confusion Matrix Testing CNN model.

The results from training the CNN to assess the quality of mangoes with anthracnose show an improved accuracy, with a Train Accuracy of 91.0% and a Test Accuracy of 88.0% when evaluated with unseen data. From the tests, it was found that predictions with errors often occur with mangoes that have just started to develop anthracnose (small black spots) or anthracnose that is not yet well-defined.

The results of testing the model for size categorization and quality assessment with Unseen data are shown in Figure 10.

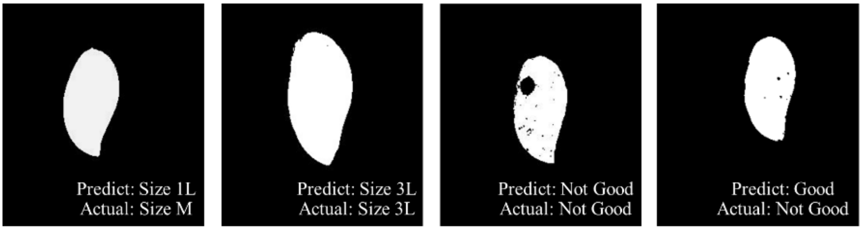

Figure 10. Example result testing with unseen data.

4. Conclusions

This paper addresses two primary objectives: size categorization and quality assessment of mangoes. In the first section, we employ Artificial Neural Network (ANN) and Convolutional Neural Network (CNN) models to classify mango sizes into four distinct categories (M, 1L, 2L, 3L). Results demonstrate the superior accuracy of the CNN model, achieving 99.16% accuracy on the training set and 88% on the test set. Conversely, the ANN model exhibited significantly lower accuracy at 25% for both training and test sets. Additionally, the CNN classification model designed to distinguish between good and bad mangoes yielded highly promising results with 91% accuracy on the training set and 88% on the test set. These findings suggest the potential for successful implementation of this algorithm within the mango industry, facilitating sorting and classification processes for both international and domestic markets in Thailand. Future research should focus on controlling the capture environment. Increasing the size of the data set to increase capacity model accuracy by adjusting the hyperparameter to be appropriate for the model considering the resources used for calculation and experiment with applying the model to other fruits.

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