# Classification of nutmeg ripeness using artificial intelligence

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**ABSTRACT**

Nutmeg seeds can produce a lot of oil if they have optimal maturity. In other words, they have little moisture content. Based on observations made at one of the refineries in Sukabumi, farmers do not pay attention to the maturity level of nutmeg seeds after drying which can cause a decrease in the quality of nutmeg seeds and the quality of the oil produced. This study aims to make it easier for nutmeg farmers to classify the maturity of nutmeg seeds. This study used the convolutional neural network (CNN) method to help with classification problems and several image processing methods. This program will be run through an Android application. When the application containing this CNN model is run, the camera system will turn on, and the program will classify in real-time nutmeg objects into 1 of 3 class labels namely LowQuality, MidQuality, or HighQuality class labels classifying. The results will be displayed on the application screen, the results are displayed in the form of class names and scores. The results of CNN model training accuracy are 97.92%.



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## 1. INTRODUCTION

Nutmeg is one of the plants originating from Indonesia with a high value. The plant with the Latin name *myristica fragrans* is classified as a type of spice plant and has the potential benefits of almost all parts of the nutmeg plant. In addition to nutmeg pulp which can be utilized as candied nutmeg, nutmeg syrup, pickles, jams, and dodol in the culinary field, *myristica fragrans* has been widely used for traditional medicine to treat several diseases, besides *myristica fragrans* has the potential as an antimicrobial antioxidant, anti-inflammatory, antiulcer, anticancer, aphrodisiac, and various other activities because it contains various phytochemicals such as lignans, neolignans, diphenylalkanes, phenylpropanoids, and terpenoid [1]–[4]. The nutmeg plant parts, namely seeds, mace, and nutmeg oil, also have high economic value and are export commodities because Indonesia is the largest nutmeg producer in the world, where most nutmeg plantations in Indonesia are cultivated by community plantations and the rest by large plantations. According to Indonesian plantation development statistics, nutmeg production in Indonesia in 2021 reached 39,577 tons [5]. Nutmeg essential oil contains up to 80% trimyristin, and trimyristin is a whitening agent for the skin or whitening agent. Nutmeg, especially nutmeg, is a source of essential oil with high economic value because this part contains around 20% to 40% fixed oil [6].

Indonesia is the largest producer and exporter of nutmeg on the world market. Sukabumi is one of the regencies in West Java that has the largest nutmeg plantation, with an area of 1,679 ha. Based on the results of observations, we made at one of the distillery in the Sukabumi area, nutmeg farmers did not pay attention to the maturity level of nutmeg seeds after drying which resulted in nutmeg seeds with low maturity mixed with nutmeg seeds that had an optimal maturity level. This has become a common problem for nutmeg refiners. The oil content in nutmeg plants is most found in nutmeg parts of nutmeg seeds, the oil in nutmeg seeds will be maximum when the nutmeg seeds have a little moisture content or in other words maximum drying. The drying process is one way to reduce the moisture content of nutmeg seeds to reach the standard. According to Jaiyeoba *et al.* [7], the moisture content will decrease as the maturity level of the seeds increases, which means that the harvest time or maturity level of the fruit will affect the quality of nutmeg after drying. Ignorance of farmers about the importance of harvesting and post-harvest processes that can cause a decrease in the quality of nutmeg.

This research is important to make it easier for nutmeg oil refiners to classify the maturity of nutmeg seeds. This study uses the convolutional neural network (CNN) method as one of the deep learning technologies to help with classification problems. This deep learning uses a simpler network scheme with fewer connections that are computationally much more efficient [8]. CNN was chosen because of research conducted by Bogar *et al.* [9]. Seeing the rapid development of mobile technology, this research will utilize Android mobile technology to facilitate the community, especially nutmeg oil refining entrepreneurs [9].

## 2. RELATED WORKS

CNN is an algorithm that already exists but is widely developed by several researchers in the field of deep learning. This study is inseparable from previous research as a reference. Several studies have focused on the development of CNNs across various objects.

Melinda *et al.* [9] introduces a mobile phone application capable of differentiating individuals with autism spectrum disorder (ASD) from those with typical brain signals, based on asynchronous EEG brain signals. It develops a preprocessing algorithm and utilizes the BCI2000 EEG data signal, making the process automated using Python. Furthermore, the study employs a deep learning CNN as the output model, deployed using Python-Flask. This enables the diagnosis of EEG signals for ASD and normal patients to be accessible across various platforms through a REST API. Bacus and Linsangan [10] classify diseases in papaya leaves using MobileNet's CNN architecture. The study used 1,394 image data and managed to obtain a high accuracy average of 91.667%. There are things that need to be underlined in this study, namely that the dataset used is an imbalanced dataset so that there is the potential for overfitting the model.

Research by Paulson and Ravishankar [11] is aimed at identifying types of herbal plants using artificial intelligence or deep learning technology. There are 64 types of herbal plants that will be identified by the CNN model and the visual geometry group (VGG) pre-train model version 16 and VGG version 19. The results of this study give CNN a good accuracy of about 95.79%, VGG16 of 97.8%, and VGG19 of 9.6%. Research by Roslan *et al.* [12] purposed to investigate the performance of CNN on dataset of herbal plants as medicine. The dataset used is a dataset of herbal plants on the Island of Pinang, Malaysia with original data and augmented additional data. The results of this study testing the model with the original data resulted in 75% accuracy and testing the model with the original data and additional data resulted in 88% accuracy. So it can be concluded from this research that the accuracy of the model can increase with the amount of data.

Wang *et al.* [13] detecting diseases and pest infections in plants using CNN architecture called ultra-lightweight efficient network. This architecture consists of 2 part modules, namely the feature extraction module that adopts residual depth-wise convolution and the qualification module that accepts multi-scale features enhanced by spatial pyramid pooling layer. As a result, the model with this architecture produces good results and has a lightweight performance. Wiryana *et al.* [14] classify store products by using the CNN algorithm. The test is conducted with 1,050 product images divided into 35 labels and divided into three data, namely 80% data training, 10% data validation, and 10% data test. The image used is preprocessed with a size of 256×256 pixels. The data was trained with six convolution layers and an epoch of 50 with an execution time of 33 minutes so as to achieve an accuracy of 91.37%.

Desai *et al.* [15] classify flower types by using the CNN algorithm. In this study using CNN architecture, namely VGG19 as an extractor feature from flower image data. The results of this study obtained 100% accuracy for training and 91.1% for validation for 17 flower type classes. Dyrmann *et al.* [16] classify plant species by using deep convolutional neural network (DCNN) algorithm. The network was engineered from scratch by being trained and tested on a complete of 10,413 pictures containing 22 weeds and plant species within the early stages of growth. For these 22 species, this network is in a position to realize a classification accuracy of 86.2%.

Rathi *et al.* [17] classify fish species by using DCNN algorithm and image processing methods. The image processing methods used are Otsu binarization, dilation, and erosion. The results of this study obtained an accuracy of 96.29%. Liew *et al.* [18] classify gender by using CNN algorithm. This study used publicly available datasets namely SUM and AT&T. The input image size used was 32×32. The accuracy results on each dataset were 98.75% for SUM and 99.38% for AT&T.

Vishnupriya and Meenakshi [19] classified music genres using neural network (NN) algorithms and mel frequency cepstral coeficient (MFCC) feature extraction. The dataset in this study covers ten different genres. The result of this study obtained 76% accuracy for training. Lu *et al.* [20] classify fruits by using CNN algorithm. Designed CNN using six layers consisting of convolution layers, pooling layers, and fully connected layers. The result of this study obtains 91.44% accuracy better than three state-of-the art: Support vector machine, wavelet entropy, and genetic algorithm. Razali *et al.* [21] classifying nutrient deficiencies in oil palms on leaves using the CNN algorithm. The study used 180 datasets and used several CNN architectures. The results of this study Alexnet became an efficient architecture with few layers.

## 3. METHOD

The method will explain in detail about the general description of the application and the stages in preparing data for the model in this study. The stages of preparing image data start from collection until the data can be used by the model including resizing data, augmentation of image data, and processing of image data. So that it can be understood for development in the future.

### 3.1. Overview of the application

The nutmeg seed maturity classification application will be run through a smartphone device after modeling using CNN. CNN is a deep learning model widely used for image or visual analysis purposes [22]. CNN is a development of multilayer perceptron designed to process image data [23]. The CNN structure consists of input layer, output layer, and hidden layer. Hidden layers include convolutional layers, pooling layers, rectified linear unit (ReLU), fully connected layers, and loss layers [24]. A general overview of the application to be designed will be shown in Figure 1.

Figure 1 describes in general the application we designed, when the application containing the CNN model is run or opened, the camera system will turn on, the model will read in real-time nutmeg objects. Then, the model will classify nutmeg seeds into 1 label from 3 class labels namely LowQuality, MidQuality, or HighQuality. After being classified the results will be displayed on the smartphone screen. The results that will be displayed are in the form of class name and score.

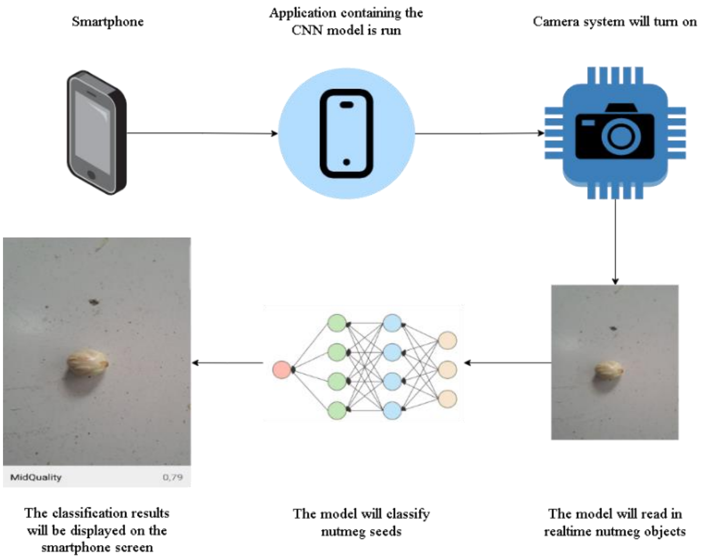



Figure 1. General overview of the application

### 3.2. Image datasets

The imagery data used was collected manually using the phone's camera and food photo box. Data is collected with several provisions in data retrieval to get the best data. The first provision, nutmeg seeds used are nutmeg seeds with an age of 3 months because nutmeg seeds at that age contain a lot of oil so it is good for distillation [2]. Second, nutmeg seeds are dried out naturally using sunlight with an average temperature of 38 °C measured using a thermometer device. Third, nutmeg seeds are dried for 8 hours for 5 days starting at 08.00 to 16.00. Fourth, nutmeg image data collection was carried out at the end of the drying day, from day 0 (after peeling) to day 5. Fifth, the distance between the camera and the object at the time of image data collection is 30 cm. These provisions are obtained based on the results of direct observation. The image data that was successfully collected with the existing provisions was 240 image data. The collected image data will not be displayed all, only one image data for each class as shown in Figure 2. Figure 2(a) is a label of LowQuality class, Figure 2(b) is a label of MidQuality class, and Figure 2(c) is a label of HighQuality class. The data labeling process in this study is based on direct observations with nutmeg seed oil refining business actors located in Sukabumi, Indonesia.

(a) (b) (c)

Figure 2. Image for (a) LowQuality, (b) MidQuality, and (c) HighQuality

Furthermore, the data will be processed so that it can be used by the model such as resizing, multiplying images, and removing the background. Image data will be resized to 224×224 size, multiply image data with augmentation techniques, and remove background using image image data segmentation. Thus, it is expected that the model can work more efficiently with smaller image sizes but there is still information that can be learned and will not process all image pixels only segmented pixels.

### 3.2.1. Resize data image

The data that has been successfully collected will be resized because the CNN model uses 224×224 as input. The image data collected has an original size of 4,032×3,024. An illustration of the image data resizing process is shown in Figure 3. In Figure 3, the original image data of 4,032×3,024 will be converted using the resize function to a size of 224×224. The purpose of this stage is to make the model work efficiently because it only processes images with a size of 224×224 and homogenizes the image size when there are images that have different sizes. Image size can be converted using the resize function.

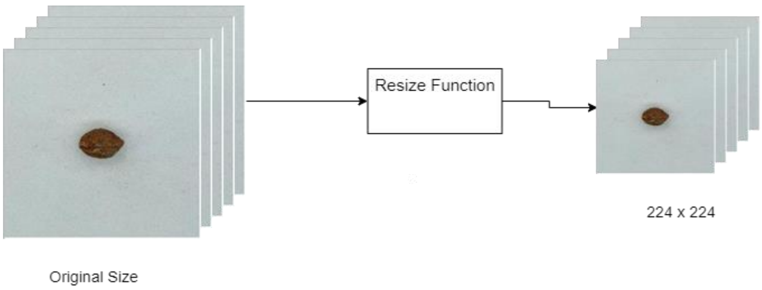



Figure 3. Image data resizing process

Furthermore, the image data will be performed in the augmentation process. The general purpose of this stage is to multiply image data by modifying the image so that it is considered different by the computer. Augmentation of images in two ways, namely rotating and flipping horizontally so that they are perceived by the computer as different image.

### 3.2.2. Image data augmentation

Image data augmentation aims to modify the image so that the modified image will be considered a different image by the CNN model, thus the image data we have will multiply [25]. Image augmentation was carried out in this study because the data used was limited, so it was necessary to do augmentation to represent the data. The image data augmentation process used is rotated with an angle of 359 degrees and flipped horizontally. The augmented image data will not be displayed all, only one will be displayed as shown in

Figure 4. Figure 4(a) is the original image before the augmentation process, Figure 4(b) is a horizontal flip augmentation image, and Figure 4(c) is a rotated augmentation image with an angle of 359 degrees.

(a) (b) (c)

Figure 4. Image for (a) original image, (b) horizontal flip image, and (c) rotate image

After going through the image data augmentation stage, originally the image data amounted to 240 data, now it has become 720 image data. The 720 images data consists of 240 original data, 240 rotate data, and 240 horizontal flip data. Next, the data will be segmented to separate parts of the image object from the background and limit the image area to be processed by the model.

#### 3.2.3. Image data segmentation

Data segmentation aims to separate the image object and background parts of the image data to limit other parts that do not need to be processed, such as the background, to increase efficiency in image data processing by the model because only the foreground is processed. Image data segmentation, the first process carried out is image data segmentation using the Otsu segmentation method. Furthermore, the second will be carried out morphological process based on the results of Otsu segmentation using the erosion method to obtain binary images. Finally, finding the outermost and largest contours using the region of interest (ROI) method based on the results of morphological processes or binary images so that the image object is separated from the background. The segmented image data will not be displayed all, only one will be displayed as shown in Figure 5. Figure 5(a) is the original image before the segmentation process, Figure 5(b) is a segmented image using the Otsu method, Figure 5(c) is an inverted image to obtain a binary image on the erosion method, Figure 5(d) is a binary image of the result of the erosion morphology method, and Figure 5(e) is the image of finding the outermost using the ROI method.

(a) (b) (c) (d) (e)

Figure 5. Image for (a) original image, (b) segmented image, (c) inverted image, (d) binary image, and (e) ROI image

#### 3.2.4. Model training and testing

The CNN architecture model used in this research is CNN MobileNet architecture, CNN MobileNet architecture is used because one of the objectives of this research is to implement the CNN model that has been made into Android devices. MobileNet architecture is a CNN architecture compatible with android devices so MobileNet was chosen in this research. After the image dataset is augmented and segmented, the image dataset will be used to train the model and test the model with a data proportion of 80% training data or 576 image data from 720 image data with the same amount of data from each nutmeg category and 20% testing data or 144 image data from 720 image data.

## 4. RESULTS AND DISCUSSION

### 4.1. Data processing results

The data processing results include segmentation using Otsu, image morphology segmentation through erosion, and finding the outermost contour using the ROI method to retrieve image objects. Furthermore, if the image and background objects have separate image data will be used as datasets for the CNN model. The results for each class can be seen in Table 1. It appears that some parts of the data are being wasted in Table 1, particularly in the LowQuality category. It seems that the segmentation process is not perfect, which is causing some object parts to be lost. To improve the results of data processing, it may be necessary to refine the segmentation process.

Table 1. Data processing results

| Classes | Result |
|---|---|
| LowQuality |  |
| MidQuality |  |
| HighQuality |  |

## 4.2. Results from creating and training the model

This section will discuss the performance and training results of the CNN classification model created and trained using the data processing results presented in Table 1. The training model results are presented as accuracy and loss validation training graphs. These graphs are shown in Figure 6. Figure 6 is a graph showing that model performance has good results because the training validation accuracy graph shows the accuracy of each epoch moving close to 1 or 100%, precisely at 0.9792 or 97.92%. Then, the training and validation loss graph shows a bit of data that the model cannot recognize marked with a descending graph at each epoch. So, it can be concluded that the model that has been made gets good results.

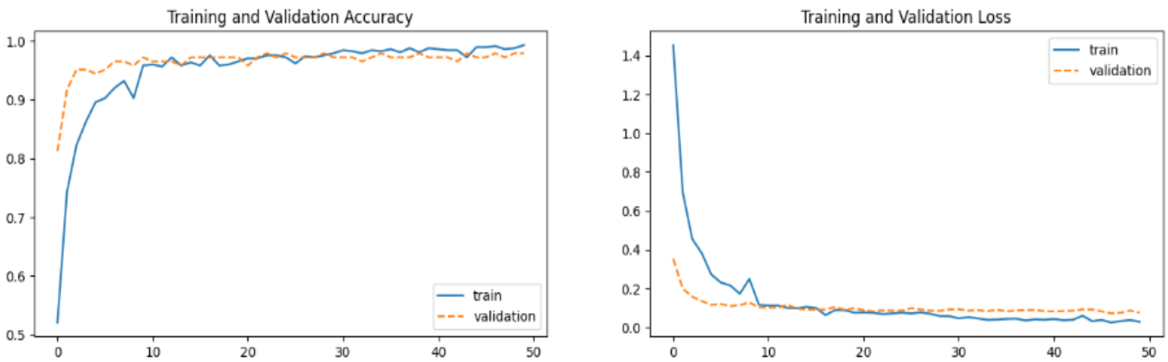



Figure 6. The training model results

The results of the model's performance in classifying are shown in the confusion matrix shown in Figure 7. Figure 7 is a confusion matrix that describes the performance of the model. This confusion matrix can be known as the accuracy value, precision value, recall value, and F1-score value. The confusion matrix in Figure 7 is then calculated to determine the accuracy value, precision value, recall value, and F1-score value. These values are used to find out whether the model that has been created is a good model. The calculation results are shown in Tabel 2.

Based on Table 2, it can be concluded. First, the model has high accuracy for test data, reaching 100% for all classes. This shows that the model can classify data accurately. Secondly, the precision value on the model for all classes reaches 100%. This indicates that of all the positive predictions made by the model, all of them are correct, and none of the predictions are wrong. Third, the recall value on the model is also very good for the "LowQuality" and "MidQuality" classes, with a value of 100%. As for the high class, recall reached 92.3%, indicating that most samples included in the "HighQuality" class were identified by the model. Fourth, all classes have a high F1-score, reaching 100% for the "LowQuality" and "MidQuality" classes and 95.9% for the "HighQuality" classes. Fifth, the model shows uniform performance and good performance in all classes, without either class having lower performance compared to the others.

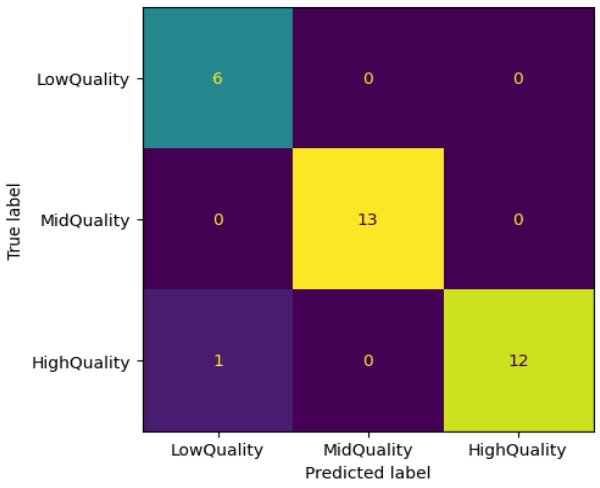



Figure 7. Confusion matrix

Table 2. The results of the calculations confusion matrix

| Confusion matrix | LowQuality | MidQuality | HighQuality |
|---|---|---|---|
| True negative | 6 | 13 | 12 |
| True positive | 0 | 0 | 0 |
| False positive | 0 | 0 | 1 |
| False negative | 0 | 0 | 0 |
| Accuracy | 1.0 (100%) | 1.0 (100%) | 1.0 (100%) |
| Precision | 1.0 (100%) | 1.0 (100%) | 1.0 (100%) |
| Recall | 1.0 (100%) | 1.0 (100%) | 0.923 (92.3%) |
| F1-Score | 1.0 (100%) | 1.0 (100%) | 0.959 (95.9%) |

Based on the existing points, it can be concluded that the model has a very good ability to classify into three different classes, consistent performance and high matrix evaluation values show that this model can be relied upon in performing classification tasks on the given data. However, it is important to remember that these results are based on the data that has been provided, and model performance may vary on different data. This requires further testing using data that is completely separate from the training data to validate the performance of the model and ensure that the model has good generalization capabilities.

### 4.3. Model implementation test results

Model implementation test results are an analysis of model test results that have been successfully implemented into Android applications. Tests are carried out using new nutmeg image data to test whether the model that has been created and implemented can classify if new data is present. This testing phase is a very important stage because it determines whether the model can be used according to the purpose of this study. This stage will display new test data that was correctly classified by the model, and new test data that was incorrectly classified by the model. Test results of the correct data classified by the model are shown in Table 3. Table 3 is the test result of new test data with models that have been implemented into the Android application. The results show that the model can classify correctly. Things that must be underlined in testing using various camera distances with objects, various backgrounds, various angles, and a lot of data with a good score.

The results of testing the model are not entirely correct, there are still misclassified data. This is natural because when viewed from the accuracy itself is not perfect. Test results of data incorrectly classified by the model are shown in Table 4. Table 4 is the test result of new test data with models that have been implemented into the Android application. The results showed that the model was wrong in classifying some new data. This is reasonable because the accuracy of the model itself is not perfect.

Table 3. Test results of the correct data classified by the model

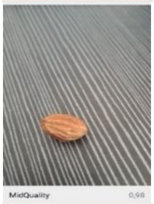
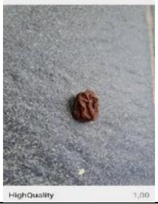
| Result | Actual classes | Predict classes | Description |
|---|---|---|---|
|  | LowQuality | LowQuality | Succeeded with an accuracy 100% |
|  | MidQuality | MidQuality | Succeeded with an accuracy 98% |
|  | HighQuality | HighQuality | Succeeded with an accuracy 100% |

Table 4. Test results of the wrong data classified by the model

| Result | Actual classes | Predict classes | Description |
|---|---|---|---|
|  | LowQuality | HighQuality | Fail |
|  | HighQuality | LowQuality | Fail |
|  | LowQuality | MidQuality | Fail |

### 4.4. Application test results

Application test results are application tests that have been made into several Android devices with different specifications. The purpose of this test is to assess the extent to which the application can work well with devices that have limited specifications. The test results are shown in Table 5. Table 5 is the test result of Android applications that have been made into several Android devices with various specifications. Performance is a parameter to measure whether the application can run properly on various types of Android systems, the display is a parameter to measure whether the application has a responsive display in various screen sizes, and model is a parameter to measure whether, with different camera specifications, the model can still classify nutmeg.

After conducting several series of tests on the models and applications that have been made, it can be concluded that the model is quite good at classifying the maturity level of nutmeg seeds. The model can be implemented into Android applications so that it can make it easier for potential users to classify to minimize errors and make time efficiency. However, in addition to the success in making models and implementing models into Android applications, there are obstacles such as models that are wrong in classifying and do not rule out the possibility that the model will continue to be developed both structurally and how to process data.

Table 5. Application test result

| Device | Specifications | Applications | | Models |
|---|---|---|---|---|
| | | Perform | Display | |
| Samsung A33 | Main camera 48 MP, screen size 6.4, RAM 8 GB, storage 128 GB, versi version Android 12 | Running | Good | Can classify data |
| Samsung galaxy m22 | Main camera 48 MP, screen size 6.4, RAM 6 GB, Storage 128 GB, version Android 11 | Running | Good | Can classify data |
| Samsung j2 prime | Main camera 8 MP, screen size 5.0, RAM 1.5 GB, storage 8 GB, version Android 6.0 | Running | Good | Can classify data |

## 5. CONCLUSION

Based on the results of the design and testing in this study, it can be concluded that the creation of a model that can classify the maturity level of nutmeg seeds using artificial intelligence has been successfully carried out, and the implementation of the model into the android application has been successfully carried out. The training accuracy result of 97.92% indicates that the CNN model is effective in recognizing the features contained in the image, this is a pretty good result. The results of testing on models and applications with new test data also showed good results, the model was able to classify new test data into one of three existing classes. Then, for testing the application also gets good results, the application can run properly on several Android devices with different specifications. From this result, it can be developed again such as improving the results of data processing because there are still some parts of the object wasted due to the image data segmentation process so it needs to be refined again for further research because the part of the object must have wasted information. Then there are new test data that are misclassified so that future research can refine the model structure and multiply the training data so that it can improve the level of accuracy. Research can be further developed by implementing classification models into devices other than Android so that it can help in the industrial field.

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