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Development of a Mobile-Based Application for Classifying Caladium Plants Using the CNN Algorithm

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ABSTRACT

Caladium is a popular ornamental plant and has business potential. However, difficulties in recognizing the type of Caladium often occur because of the similarities in shape, pattern, and color of the leaves between the different kinds of Caladium. To overcome this problem, research will use machine learning with the Convolutional Neural Network (CNN) algorithm to build a mobile application that can accurately classify four types of Caladiums. The data set used is 1200 data with four classes; each class has 300 data. The best model is found with the parameter epoch 100, learning rate 0.001, and batch size 64. The model is then implemented in a mobile application with two menus, "Take a photo" and "Choose an image," which will display the classification output and confidence values of the four types of Caladiums. Testing with 30 test data per class achieves 0.975 accuracy on both menus. On the "Take a photo" menu, precision is 0.974, recall is 0.9725, and f1-score is 0.965. Meanwhile, on the "Choose an image" menu a precision and recall value is 0.975, and f1-score value of 0.97.

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1. INTRODUCTION

During the COVID-19 pandemic in Indonesia, people's interest in cultivating ornamental plants increased due to boredom due to limitations in outdoor activities[1]. Caladium is a decorative plant that grows in demand and is popular among the public. This is because the plant has unique and distinctive characteristics, namely broad leaves extending forward in the shape of a heart, thin leaves, striking and unique color patterns such as green, white, pink, and red, tuberous, and does not have a stem but has elongated leaves[2]. The price of this plant is also increasing due to the large number of enthusiasts, especially during the Covid-19 pandemic. The price for one caladium ornamental plant varies from around IDR 35,000 to IDR 233,000 [3].

Caladium is a family of Araceae originating from America and areas with tropical climates [4]. Currently, around 20 types of caladium plants are widely cultivated in Indonesia. Similar shapes and color patterns make ornamental Caladium challenging to differentiate[5]. Someone needs to study the characteristics of each type of caladium so that everything runs smoothly when recognizing ornamental caladium plants. With technological advances, every kind of Caladium can be identified through applications built to classify ornamental caladium plants.

The way that can be used to classify and identify caladium ornamental plants is using image processing techniques. Image processing consists of the processing to extract leaf characteristics for classification [6]. The technology to recognize and differentiate similar images can use deep learning

with the Convolutional Neural Network (CNN) algorithm. The CNN algorithm is a subfield of deep learning that is most widely used for image classification[7]. Deep learning is a subfield of machine learning that uses the application of the neural network concept, which has many layers that can solve problems with large data sets[8].

To implement the need for identifying caladium plants, previous research was carried out by Yoga Purna Irawan and Indah Susilawati in 2022, with the title Classification of Aglaonema Types Based on Leaf Image Using Convolutional Neural Network (CNN). The data sets used in this research include Aglaonema Commutatum, Costatum, Deborah, King of Siam, and Snow White. The data set used in this research is 70% training data and 30% test data out of 100% dataset. The test used five images of aglaonema plants, and the plants had 10 data sets for each of the five plants. The results of testing this system produced an average accuracy value of 96%[9].

From this research, the CNN algorithm produces high accuracy values[10]. This makes the CNN algorithm the best algorithm for classifying images, including the classification of caladium ornamental plants. The CNN algorithm was chosen as the method that will be used to classify caladium ornamental plants because it can produce a high level of accuracy in image processing.

This research will build an application that can classify caladium ornamental plants using the CNN (Convolutional Neural Network) algorithm. The data set used in this research uses four types of Caladiums: Alocasia Caladium, Amazon Caladium, Bicolor Caladium, and White Queen Caladium. Of the 20 types of Caladiums widely cultivated by the community, four types were used as the object of this research because they have similarities in shape, color, and pattern of leaves, making them difficult to differentiate. Alocasia caladium and Amazon caladium are similar in leaf shape and color. In contrast, bicolor and white queen caladium are classified because they have similar leaf shapes and red-green leaf colors. This research was developed using a mobile application where users can select images of ornamental plants from their respective Android file storage and take photos directly.

2. METHOD

2.1. Application Design Step

The architecture to developing a mobile application has six step Figure 1.

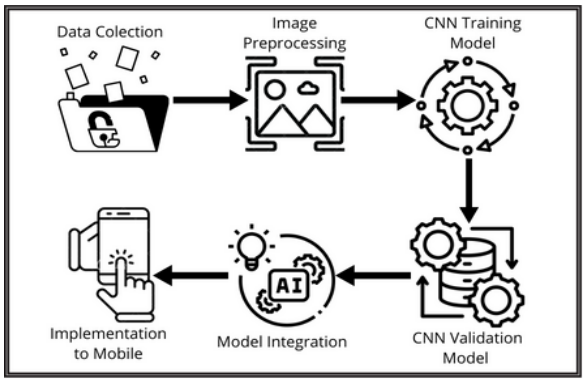


Figure 1. Application Design

The stages of implementing the model to creating an application that can classify caladium ornamental plants are as follows:

- Data Collection

  All these ornamental plants were collected independently. From the information collected, the four types of ornamental plants most used as home decoration are namely images in the form of Amazon caladium plants, Alocasia caladium plants, bicolor caladium plants, and white queen caladium plants. This research collected 4 classes in data set with each class has 300 data points, so the total is 1200 image data.

- Image Preprocessing

  Data preprocessing is carried out to process all data sets that have previously been labeled. The data that has been collected is created in a path called data. After the data is collected and labeled, the next stage is to resize and split the image data. Resize each of the photos to the same sizen128 x 128 pixels by resizing each of the pixels in the images. This occurs through

an approach known as scaling, which reduces the image's pixels without changing the size of the image as an entire. The data set is splitting into training, validation, and testing data. The dataset is separated according to the proportion of data that will be utilized for each subset, which is 70% train data (840 data), 20% validation data (240 data), and 10% test data (120 data).

- Training Model Design

  CNN algorithm trains a model to recognize images and differentiate between images. At this stage, data from training will be utilized to develop training to generate a decent model with a combination of different parameters.

- Validation Model CNN

  The validation stage uses validation data to measure the model's performance on data it has never seen before and ensure the model can be used to classify images on new data. At this stage, evaluation metrics such as accuracy, precision, recall, and F-1 score can be determined to evaluate model performance. The validation stage is used to find optimal parameters that produce high accuracy. The parameters to look for include epoch, learning rate, and batch size.

- Integration of Python to Mobile

  Models trained in Python can be integrated into mobile applications using TensorFlow Lite. TensorFlow Lite is a library from TensorFlow that can incorporate trained models into mobile applications. Integrating TensorFlow Lite into a mobile application can be done by converting a model that has been trained in Python into a format that TensorFlow Lite can understand.

- Implementation to Mobile

  To implement models that have been built in Python into Android Studio with the Java programming language. The implementation will be deployed to mobile applications to make users comfortable using the caladium plant's classification feature. Figure 2 is the mobile design architecture for integration with the CNN model.

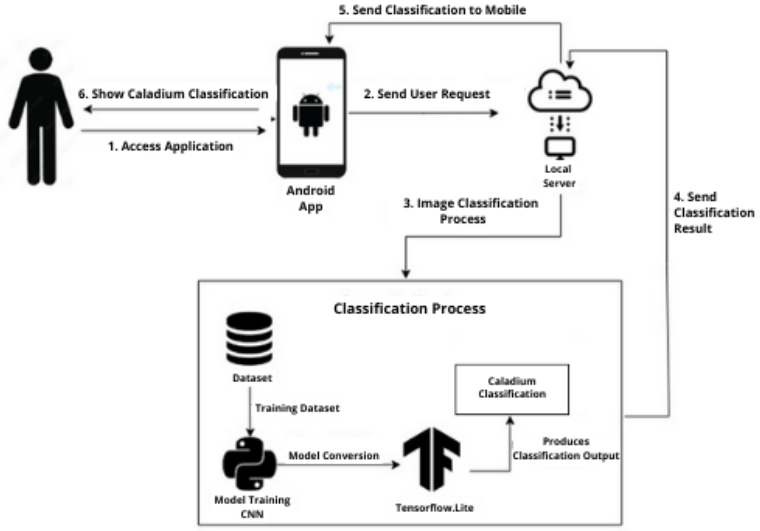


Figure 2. Mobile Architecture Integration

2.2. Caladium

Caladium is an ornamental plant that is familiar and popular among the public. The ornamental plant caladium belongs to the genus Caladium or the Caladium tribe or Araceae from South America and Central America. Four types of caladiums have similarities in shape and leaf pattern, including Alocasia, Amazon, Bicolor, and White Queen. Figure 1 is pictures of the four caladium ornamental plants with similar leaf shapes and designs.

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

Figure 3. Bicolor Caladium (a), White Queen Caladium(b), Alocasia Caladium (c), Amazon Caladium (d)

2.3. Deep Learning

Deep Learning is the study of knowing how to use computers to demonstrate human learning activities and how computers can improve themselves to acquire new knowledge and skills, identify existing knowledge, and continue to improve performance and achievement[11]. Machine learning is a subfield of artificial intelligence focusing on machine learning to carry out human activities. Artificial Intelligence is the ability of computers to know and simulate human intelligence so that computers can do what humans can, which requires intelligence[12], [13] One of the deep learning method techniques is supervised learning. Which is supervised learning, the learning process of which is based on data that has labels. Supervised learning consists of regression and classification. Regression is used to predict output results from continuous values. Type is used to identify categories or tags of observations based on data that has been trained. The program will learn from data collection or train data and then classify it into several classes or groups. An example of applying classification is the classification or grouping of plants based on leaf images, where the program will be trained to recognize and manage images that have been trained to recognize image objects and group them based on predetermined categories and labels. Supervised learning consists of regression and classification. Regression is used to predict output results from continuous values. Classification is used to identify categories or labels of observations based on data that has been trained. The program will learn from data collection or train data and then classify it into several classes or groups[14]. An example of applying classification is the classification or grouping of plants based on leaf images, where the program will be trained to recognize and manage images that have been trained to recognize image objects and group them based on predetermined categories and labels.

2.4. Convolutional Neural Network (CNN)

CNN is an algorithm used in deep learning and part of MLP (Multi-Layer Perceptron) designed to manage and recognize images or other images with two or more dimensions. CNN is among the most popular neural network categories[15], especially for high-dimensional data such as images and videos. CNN uses a supervised learning method to classify labeled data to manage data in 2 dimensions[16]. The steps in CNN include convolutional layers, pooling layers, flattening layers, and complete connection layers. CNN has three layers, including the input layer, hidden layer, and output layer. Hidden layers perform feature extraction by performing different calculations. There are several layers in the hidden layer, including the convolution layer, ReLU layer, and pooling layer[17]. The CNN architecture can be seen in as follows Figure 4.

2.4. Evaluation

The evaluation stage on CNN uses a confusion matrix to measure a classification model's performance[18]. A confusion matrix is a matrix table method containing test data rows predicted to be true and false by the model. The output of the confusion matrix to measure problems in binary classification is true is one and false is 0. Measuring model performance with confusion matrix can be done by calculating performance metrics, namely: accuracy, precision, recall and F1-Score[19].

1. Accuracy: In the multi-class classification, there are more than two targeted classes.

$$accuracy = \frac{TP}{Total\ Dataset} \quad (1)$$

2. Precision: comparison value to get the result of how often a prediction is positive when the model makes a positive prediction.

$$Precision = \frac{TP+TN}{TP+FP} \quad (2)$$

3. Recall: the success of model performance to get back information in the form of the success of the model can successfully capture all positive targets.

$$Recall = \frac{TP}{TP+FN} \quad (3)$$

4. F-1 Score: get a comparison of the average precision and recall values.

$$F-1\ Score = \frac{(2*Recall*Precision)}{(Recall+Precision)} \quad (4)$$

3. RESULT AND DISCUSSION

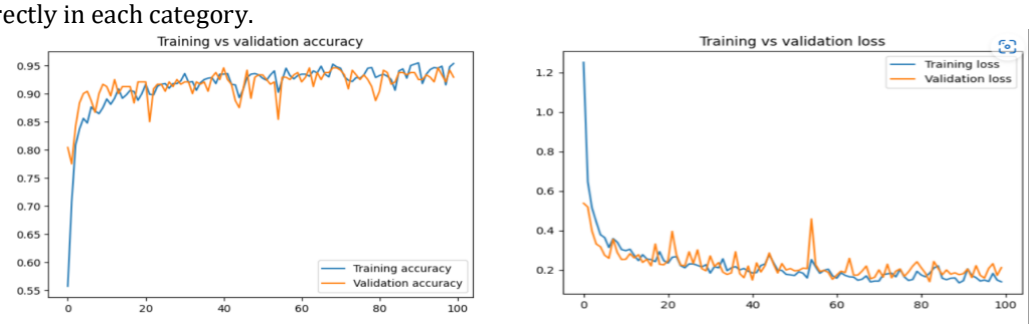
3.1. CNN Model Accuracy

The results of each experiment are analyzed to determine the performance of each trained model, which is evaluated using loss and accuracy metrics. The experiment can be seen in Table 1

Table 1. Parameter Experiment Results

Experiment	Epoch	Batch Size	Learning Rate	Loss	Accuracy
1	15	16	0.1	1.4	0.25
2	15	32	0.01	0.784	0.56
3	15	64	0.001	0.374	0.85
4	25	16	0.1	1.404	0.25
5	25	32	0.01	0.482	0.80
6	25	64	0.001	0.295	0.89
7	50	16	0.1	1.387	0.25
8	50	32	0.01	0.889	0.60
9	50	64	0.001	0.198	0.91
10	75	16	0.1	1.404	0.25
11	75	32	0.01	1.179	0.5
12	75	64	0.001	0.187	0.93
13	100	16	0.1	1.395	0.25
14	100	32	0.01	1.386	0.25
15	100	64	0.001	0.197	0.95

Table 1 shows that, with 100 epochs, batch size = 64, and learning rate = 0.001, it is an optimal experiment and produces good and higher accuracy compared to other experiments. The confusion matrix results that have been carried out on testing data with 30 data per class each show how good the model used is in making predictions. A graph depicting training validation accuracy and validation loss can be seen in Figure 5. The confusion matrix illustrated in Figure 6 for the data predicted correctly and incorrectly in each category.



(a) (b)

Figure 5. Training Validation Accuracy (a) and Loss (b)

	precision	recall	f1-score	support
0	0.97	1.00	0.98	30
1	1.00	0.87	0.93	30
2	1.00	0.93	0.97	30
3	0.86	1.00	0.92	30
accuracy			0.95	120
macro avg	0.96	0.95	0.95	120
weighted avg	0.96	0.95	0.95	120

Figure 6. Confusion Matrix CNN's Model

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The results of testing the model using testing data showed an accuracy of 95% and train loss of 0.197. This level of accuracy is relatively high because the model can recognize the characteristics of the four types of caladiums, and the model can minimize the possibility of errors in classifying ornamental plants. The hyperparameters and models that have been obtained will be implemented in a mobile-based application with 2 menus, namely classified directly and the choose image menu.

3.2. Application Results

In the application, two menus can be used, including the take photo menu to take an image that will be classified directly and the choose image menu to use if you want to select an image that will be classified from each user's gallery. Figure 7 is the interface of application.

Figure 7. Classification Caladium in Mobile Application

3.3. Evaluation Mobile Application

This section will calculate two types of menus that is Take Photo Directly Menu and Choose Image Menu. On each menu, caladium varieties will be evaluated thirty times. The menu will take 30 straight shots of the plant. When select an image, it will utilize 30 image data that have been split up into testing data. Each menu presents the value of the confusion matrix.

3.3.1. Evaluation in Menu Take Photo

Menu Take Photo carried out directly on caladium leaves. This menu will test every variety of caladium ornamental plant thirty times. The model's performance parameters will be calculated using a confusion matrix in the measurement process. The confusion matrix results after testing by taking photos of Caladium directly illustrated in Table 3 and Table 4.

Table 3. Test Results on the Take Photo Menu

Target	Prediction			
	Amazon	Bicolor	Alocasia	White Queen
Amazon	29	1	0	90
Bicolor	28	2	0	90
Alocasia	30	0	1	89
White Queen	30	0	2	88

Table 4. Prediction Results on the Take Photo Menu

Target	Prediction			
	TP	FN	FP	TN
Amazon	29	1	0	90
Bicolor	28	2	0	90
Alocasia	30	0	1	89
White Queen	30	0	2	88

The result of accuracy, recall, precision and F-1 Score values is as follows are:

a. Accuracy = 97,5%
b. Precision = 97,4%
c. Recall = 97,25%
d. F-1 Score = 96,5%

3.3.2. Evaluation in Menu Choose Image

Menu Choose Image that have previously collected testing data from 10% of the dataset (120 data) are used for image testing. The data has been split based on data splitting during the picture processing phase. Every piece of data undergoes testing and is condensed into a confusion matrix, which is used to determine how well the model performed on the mobile application. The following are the confusion matrix results after testing by choosing an image from a gallery user illustrated in Table 5 and Table 6.

Table 5. Test Results on the Choose Image Menu

Target	Prediction			
	Amazon	Bicolor	Alocasia	White Queen
Amazon	29	1	0	90
Bicolor	28	2	0	90
Alocasia	30	0	1	89
White Queen	30	0	2	88

Table 6. Prediction Results on the Choose Image Menu

Target	Prediction			
	TP	FN	FP	TN
Amazon	30	0	0	90
Bicolor	27	3	0	90
Alocasia	30	0	0	90
White Queen	30	0	3	87

The result of accuracy, recall, precision and F-1 Score values is as follows:

a. Accuracy = 97,5%
b. Precision = 97,5%
c. Recall = 97,5%
d. F-1 Score = 97%

4. CONCLUSION

The conclusions obtained from this final assignment research include by applying the Convolutional Neural Network algorithm, this final project research has succeeded in classifying caladium ornamental plants into four types of classes: Amazon caladium, bicolor, Alocasia, and white queen. This research uses a data set of 300 in 4 classes, conducting several experiments to determine the best parameter values. The highest accuracy value in this study used epoch 100, learning rate 0.001, and batch size 64, with an accuracy value of 95%. This research has developed a mobile-based application with two menus: take a photo directly and choose an image from the user's gallery. After testing the application from both the take photo and choose image menus, an accuracy value of 97.5% was obtained. To facilitate future study, a real-time object detection-based application that can both categorize caladium in a single frame and present all the caladium's information is hoped to be developed.

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