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Hyperparameter Optimization Using Hyperband in Convolutional Neural Network for Image Classification of Indonesian Snacks

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Abstract. Indonesia is known for its traditional food both domestically and abroad. Several cakes are included in favorite traditional foods. Of the many types of cakes that exist, it is visually easy to recognize by humans, but computer vision requires special techniques in identifying image objects to types of cakes. Therefore, to recognize objects in the form of images of cakes as one of Indonesian specialties, a deep learning algorithm technique, namely the Convolutional Neural Network (CNN) can be used.
Purpose: This study aims to find out how the Convolutional Neural Network (CNN) works by optimizing the hyperband hyperparameter in the classification process and knowing the accuracy value when hyperband is applied to the optimal hyperparameter selection process for classifying Indonesian snack images.
Methods/Study design/approach: This study optimizes the hyperparameter Convolutional Neural Network (CNN) using Hyperband on the Indonesian cake dataset. The dataset is 1845 images of Indonesian snacks which consists of 1523 training data, 162 validation data and 160 testing data with 8 classes. In training data, the dataset is divided by 82% on training data, 9% validation, and 9% testing.
Result/Findings: The best hyperparameter value produced is 480 for the number of dense neurons 2 and 0.0001 for the learning rate. The proposed method succeeded in achieving a training value of 87.53%, for the validation process it was obtained 66.8%, the testing process was obtained 79.37%. Results obtained from model training of 50 epochs.
Novelty/Originality/Value: Previous research focused on the application and development of algorithms for the classification of Indonesian snacks. Therefore, optimizing hyperparameters in a Convolutional Neural Network (CNN) using Hyperband can be an alternative in selecting the optimal architecture and hyperparameters.

Keywords: Convolutional neural network, Hyperband, Hyperparameter optimization, Image classification, Jajanan Indonesia
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INTRODUCTION

Recent developments in image processing technology have made it possible for people to create systems that recognize something in digital images. Image processing is also a type of technology to solve problems related to image processing. In image processing, images are processed so that they can be used for further applications [1]. The use of digital image processing technology is also expected to create applications to make it easier for people to identify types of food [2]. The need for food is one of the most important daily needs in human life. Snacks are one of the favorite snacks of the Indonesian people and are also a way to meet food needs. Traditional cakes are snacking that people like because they are dense and filled. Various traditional cakes are currently sold in the market. Traditional cakes have very different textures, shapes and colors and some are similar to one another making it difficult to identify the cake [3].

Traditional cake is a form of culture that reflects the natural potential of the area. Developed from generation to generation. The development of the times in Indonesia has led to changes in history and culture, one of which is traditional food or snacks. Traditional snacks also have various characteristics and tastes that range from sweet to savory, people in Indonesia are quite familiar with various types of

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traditional snacks from their respective regions. [4]. People in the digital era have the habit of taking photos of food before eating, which is a way of life. Then the photos obtained will be uploaded to social media. The dissemination of traditional food photos that are still lacking in identification encourages this research to conduct research on the classification of traditional food images [3].

Image processing is a science related to improving image quality (contrast enhancement, color transformation, restoration), image transformation (rotation, translation, scaling, geometric transformation), obtaining features of an image (feature extraction) that are optimal for analysis purposes, carry out the process of recognizing objects contained in the image, and performing compression [5].

Recent developments in image processing technology have made it possible for people to create systems that recognize something from a digital image [6]. Image processing is also a type of technique for solving problems related to image processing. In image processing, the image is processed so that it can be used for further applications [1]. Digital image is one of the media in technology that is easy to find in everyday life. The ease of accessing digital images has led to various new innovations such as computer vision.

Computer Vision is an image-based form of computer science that uses pixel values to infer image content [7]. Computer Vision deals with object recognition in images, such as detecting faces or car license plates (Facebook, GoogleStreetView). It is also related to the detection of aspects of an image, such as the detection of cancer in biomedical images [8]. Computer Vision can also be interpreted with image processing related to image acquisition, classification, processing and overall coverage [9]. However, these conventional machine learning algorithms have limitations in processing raw data [7]. These limitations can be overcome by using deep learning algorithms.

Deep learning is part of machine learning that can handle large and increasing cases of data. In addition, deep learning can work well because it has concepts that work in depth like the human brain [10]. Compared to traditional computer vision techniques, deep learning allows for greater accuracy in tasks such as image classification, semantic segmentation, object detection, and simultaneous localization and mapping (SLAM) [11]. One of the deep learning algorithms that can be used to complete computer vision tasks is the Convolutional Neural Network (CNN).

Convolutional Neural Network (CNN), one of the machine learning algorithms for developing multi-layer perceptron (MLP), which can be used for image recognition. Convolutional Neural Network (CNN) was chosen because it can extract features automatically and has high image recognition accuracy [12]. Previous research was conducted by Kurnia et al. (2021) [13] with the title "Image Processing Identification for Indonesian Cake Cuisine using CNN Classification Technique" identified the image of Indonesian cakes using a convolutional neural network. This study uses a dataset of Indonesian cakes totaling 1845 images which are divided into 8 categories, namely dadar gulung, kastengel, klepon, lapis, lumpur, putri salju, risoles and serabi. The results of this study obtained an accuracy value of 65%. The drawbacks of this study are that researchers still do not discuss hyperparameters and the number of epochs is too small, so the accuracy results obtained can be even greater and much better.

In this research, optimization of the Convolutional Neural Network (CNN) hyperparameter will be carried out using hyperband, with data in the form of images of Indonesian snacks. The scenario used is to compare the results of the accuracy of the Convolutional Neural Network (CNN) model that has been optimized for hyperparameters with the accuracy results that have been carried out in previous studies with the same dataset. The hope is that by using hyperband as hyperparameter optimization, we can get optimal hyperparameter values and better accuracy results.

METHODS

This study aims to perform hyperparameter optimization on the Convolutional Neural Network (CNN) using Hyperband in the classification of Indonesian snacks. In the study by Kurnia et al. [13] shows that the use of Hyperband in optimizing the Convolutional Neural Network (CNN) hyperparameter applied to Indonesian snacks produces a good accuracy value. Therefore, the method used in this study is the Convolutional Neural Network (CNN) and Hyperband. The stages of this research consist of data splitting, data preprocessing, Hyperband optimization, model training, and model evaluation. The research method flowchart can be seen in Figure 1.

Dataset

This study uses a public dataset, namely Indonesian cake from Kaggle. This dataset has been used in a study by Kurnia et al. [13]. This data has 1845 images which are divided into 8 classes, namely dadar gulung, kastengel, klepon, lapis, lumpur, putri salju, risoles and serabi.

Data Splitting

The dataset consists of 2 parts, namely training with 1523 images and validation with 162 images. Part of the training is divided into 2 data of 82% training data and 9% validation data.

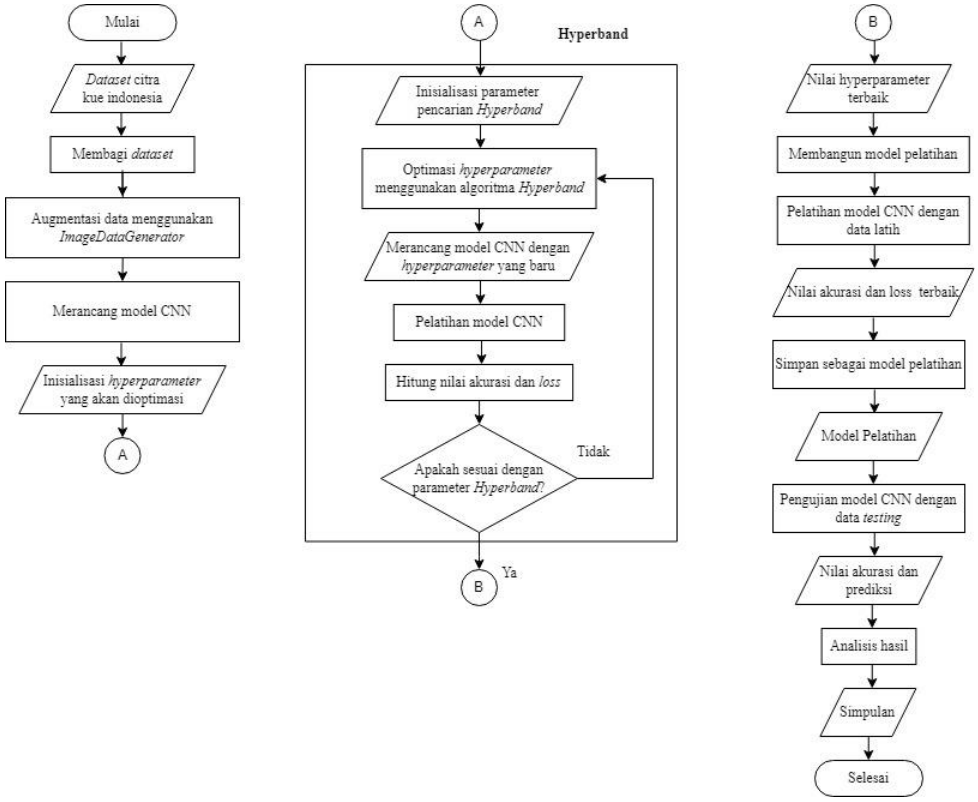

Figure 1. Flowchart of research methods

Data Preprocessing

The preprocessing data used in this study is data augmentation. Data augmentation not only expands the size of the dataset, but also incorporates the degree of variation within the dataset allowing the model to generalize better to unseen data. In this study, the application of data augmentation uses ImageDataGenerator from the Keras library. The library provides various data augmentation techniques, such as standardization, rotation, shifts, and others. Table 1 shows the data augmentation technique used in this study.

Table 1. The data augmentation technique used

Data Augmentation	Nilai
Rotation_range	5
Rescale	1./255
Shear_range	0.2
Zoom_range	0.2
Horizontal_flip	True
Vertical_flip	True

Hyperband Optimization

Hyperband is a development of the Successive Halving algorithm proposed by Jamieson and Talwalkar [14] for hyperparameter optimization and call it a subroutine. Hyperband is generally an algorithm that allocates more resources to a more feasible hyperparameter configuration for a model [15]. Hyperband takes an approach that seeks to speed up Random Search through adaptive resource allocation and early stopping [16]. In Hyperband, each resource corresponds to the hyperparameter to be optimized, such as the neural network architecture, the number of layers, or the learning rate allocated to a random sample configuration. This research has limited search space for optimal hyperparameter values in Convolutional Neural Network (CNN). This limitation is done to reduce large computing resources. Limit value in this study can be seen in Table 2.

Table 1. Batasan nilai hyperparameter

Hyperparameter	Nilai
Dense Neuron 2	32-512
Learning Rate	0.1, 0.01, 0.001

In addition to limiting hyperparameter values, Hyperband optimization itself has parameters that become limitations in the hyperparameter search process, such as max_epochs and executions_per_trial. Table 3 is the Hyperband search parameters used in this study.

Table 3. Hyperband search parameters

Batasan	Nilai
Max_epochs	10
Executions_per_trial	3

Convolutional Neural Network (CNN)

Convolutional Neural Network (CNN) is one of the best learning algorithms for understanding image content and has shown good performance in segmentation, classification, detection, and other tasks related to images [17]. Convolutional Neural Network (CNN) consists of neurons, where each neuron has a weight and bias that can be learned [18]. Based on research by Lecun et al. [7], Convolutional Neural Network (CNN) has three main layers, namely convolutional layer, subsampling layer (pooling layer), and fully connected layer. Figure 2 is the LeNet-5 architecture introduced by LeCun et al. [7].

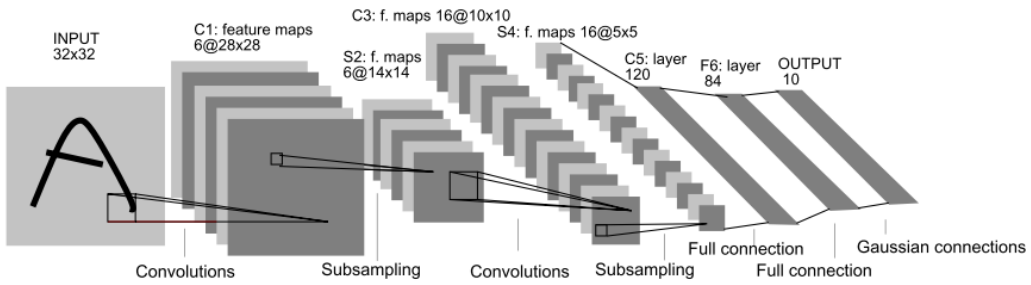

Figure 2. Architecture of LeNet-5 [18]

In this study, the Convolutional Neural Network (CNN) architecture is used in the training process and hyperparameter optimization. Hyperparameter optimization is performed on the number of dense neurons 2 in the fully connected layer and the learning rate in the model compilation process. The Convolutional Neural Network (CNN) architecture used in this study can be seen in Figure 3.

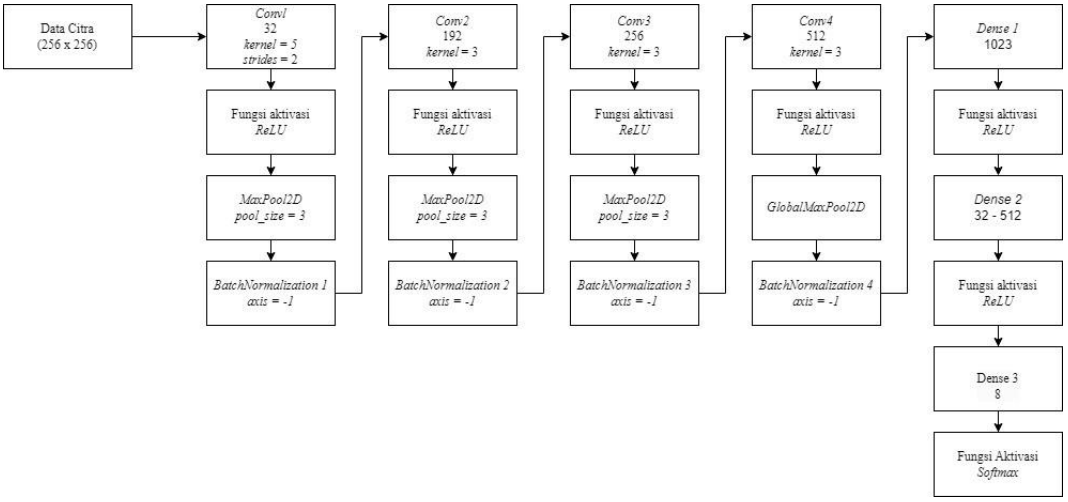

Figure 3. Convolutional Neural Network (CNN) architecture used

Model Evaluation

Model evaluation aims to evaluate the training model using testing data. This is done to determine the performance of the Convolutional Neural Network (CNN) model which has been optimized using Hyperband. The accuracy value of the model evaluation is obtained using equation 1.

$$accuracy = \frac{TP+TN}{TP+TN+FP+FN} \times 100\% \quad (1)$$

Information:
TP (True Positive) is the number of positive data that is predicted to be true
TN (True Negative) is the number of negative data that is predicted to be true
FP (False Positive) is the amount of negative data that is predicted as positive data
FN (False Negative) is the number of positive data predicted as negative data

Precision (P) represents the proportion of true positive results and can be calculated using equation 2.

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

Then a Recall (R) calculation is carried out with the aim of measuring the proportion of actual positives that are correctly identified which can be calculated using equation 3.

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

Then the last one is the F1-score which can be interpreted as the average of the precision and recall results calculated using equation 4.

$$F1 - score = 2\frac{P.R}{P+R} \quad (4)$$

The next step is the analysis of the results after the calculations have been carried out on the evaluation and the accuracy value has been obtained. In this study, an analysis of the results of the accuracy of image classification of Indonesian snacks was carried out using the CNN algorithm which has been optimized for hyperparameters using hyperband on the Indonesian snacks dataset.

RESULT AND DISCUSSION

Result

This study aims to obtain the best accuracy and hyperparameter values for Convolutional Neural Network (CNN) using Hyperband in the classification of Indonesian snacks. The optimized hyperparameters are the number of dense neurons 2 and learning rate. The Hyperband optimization process uses the Keras-Tuner library. Hyperband optimization results can be seen in Table 4.

Table 4. Hyperband optimization results

Trial	*Hyperparameter*						
	Dense 2	*Learning Rate*	*Epochs*	*Initial Epochs*	*Bracket*	*Round*	*Score*
1	480	0.0001	10	4	2	2	43,12%
2	128	0.001	10	4	1	1	43,12%
3	64	0.001	10	0	0	0	40,62%
4	192	0.001	10	0	0	0	40,41%
5	480	0.0001	4	2	2	1	37,91%
6	480	0.001	10	4	1	1	37,08%
7	448	0.001	10	4	2	2	36,04%
8	480	0.001	4	0	1	0	35,00%
9	128	0.001	4	0	1	0	35,00%
10	32	0.001	4	0	1	0	34,79%

Based on Table 4, the best hyperparameter value for dense neuron 2 is 480 and the learning rate is 0.0001 with a score of 43.12% in the 1st trial, while the hyperparameter with the smallest result is 34.79% with a dense neuron 2 and learning rate is 32 and 0.001. The hyperparameter values obtained are then used to build a Convolutional Neural Network (CNN) model at the training stage. Graph of accuracy and loss values from model training which can be seen in Figure 4.

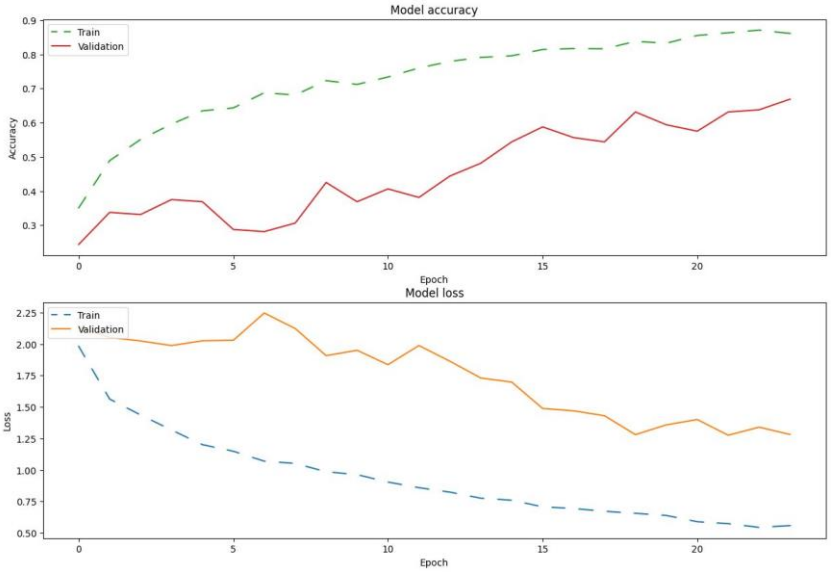

Figure 4. Graph of model training accuracy and loss values

The training model is then evaluated using testing data. Model evaluation aims to determine the performance of the training model. The accuracy and loss values of the classification of Indonesian snacks using the Convolutional Neural Network (CNN) with Hyperband are shown in Table 5.

Table 5. Accuracy and loss results from model evaluation

Accuracy	Loss
79.3%	0,8363

Furthermore, the performance measurement of the training model is carried out using the confusion matrix. Figure 5 shows the results of the confusion matrix on the model evaluation.

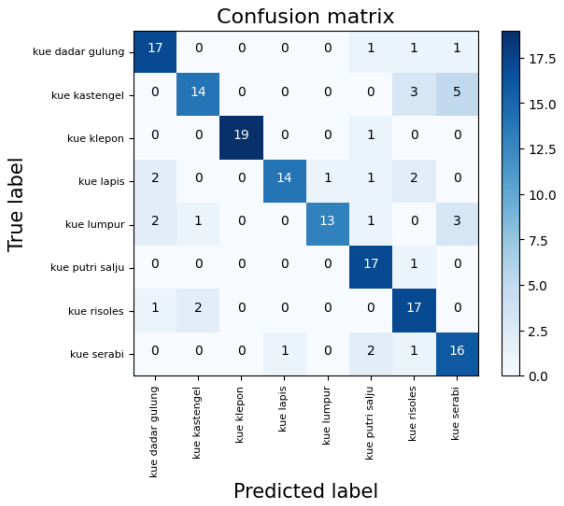

Figure 5. The results of the confusion matrix on the model evaluation

The results of the confusion matrix are then measured using performance metrics, such as precision, recall, and F1 score. Precison is the comparison between positive correct predictions and overall positive predicted results. Recall is a comparison of true positive predictions with all data that is true positive. F1 score is the average comparison between weighted precision and recall. The results of the precision, recall, and F1 scores for each class are shown in Table 6.

Table 6. Precision, recall, and F1 scores for each class kelas

Class	Precision	Recall	F1-score
Dadar gulung	77%	85%	81%
Kastengel	82%	64%	72%
Klepon	100%	95%	97%
Lapis	93%	70%	80%
Lumpur	93%	65%	76%
Putri Salju	74%	94%	83%
Risoles	68%	85%	76%
Serabi	64%	80%	71%

Based on Table 6, it can be concluded that the results of the confusion matrix from testing the Convolutional Neural Network (CNN) model with Hyperband show good results. This is indicated by the average values of precision, recall, and F1 scores which have not too much difference.

Discussion

This study applies Hyperband to the Convolutional Neural Network (CNN) hyperparameter optimization process in the classification of Indonesian snacks. The dataset used in this study is Indonesian Cake obtained from Kaggle. The performance of the resulting model can be known by the accuracy value obtained. The following is the best accuracy value from the experiments that have been carried out which can be seen in Table 7.

Table 7. The best accuracy value

Data	Accuracy
Training	87,53%
Validation	66,87%
Testing	79,37%

Based on the experiments that have been done, the resulting model is capable of classifying Indonesian snacks well. This study compares the accuracy values obtained with previous research on the classification of Indonesian snacks using the same dataset. Comparison of accuracy values is shown in Table 8.

Table 8. Comparison of accuracy values with previous studies

Author	Method	Accuracy
Kurnia *et al.* (2021)	CNN dengan 3 convolutional layer dan 1 fully connected layer	65%
Penulis	Convolutional Neural Network (CNN), Hyperband.	79,37%

The application of Hyperband in the convolutional neural network (CNN) hyperparameter optimization process can produce good accuracy values in the classification of Indonesian snacks. Classification of Indonesian snacks has a fairly high level of difficulty due to similarities in characteristics and characteristics between types of Indonesian snacks. This method can still be developed by adding variations of hyperparameters to be optimized and other architectures or algorithms.

CONCLUSION

This study succeeded in classifying 8 classes of Indonesian snacks using a Convolutional Neural Network (CNN) with Hyperband. This study uses CNN as a classification algorithm and Hyperband as a hyperparameter optimization method capable of obtaining an accuracy value of 79.37%. In addition, the application of Hyperband to the Convolutional Neural Network (CNN) hyperparameter optimization produces a hyperparameter value of 480 for the number of dense neurons 2 and 0.0001 for the learning rate.

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