Image Classification of Pandawa Figures Using Convolutional Neural Network on Raspberry Pi 4

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Abstract. Pandawa is one of the stories in wayang show consisting of five figures: Yudhistira, Bima, Arjuna, Nakula and Sadewa. This research is using Convolutional Neural Network (CNN) and apply it on the Raspberry Pi 4 to classify the puppet figures. CNN is one of the methods that can be used for classification of image data that has more than two classes. The network architecture used can classify Pandawa figures, using 1000 dataset with a size of 100 × 100 consisting of 80% training data and 20% test data. The network architecture has 3 convolution layers and 3 hidden layers, as well as 1 layer output. The classification results on the training data have an accuracy rate of 97.88% while test data has an accuracy rate of 96.5%.

1. Introduction
Wayang show is one of the cultural heritage of Indonesia that has been recognized by UNESCO in the category Masterpiece of Oral and Intangible Heritage of Humanity. The story in the wayang show is taken from the Ramayana and Mahabharata stories, which can be used as educational and entertainment media. The show is usually played by a Dalang accompanied by traditional music Gamelan. The development of the technology causes wayang show less desirable by the younger generation, because it has been replaced by online games and social media. Elaborate language and long show time, increasingly alienating the younger generation of wayang show [1].

Pandawa is the story of the five brothers Yudhistira, Bima, Arjuna, Nakula and Sadewa taken from the Mahabharata saga. In the story of Pandawa can give a moral lesson for the young generation, so hopefully the young generation can recognize the figures to help preserve the art of wayang show as a cultural heritage [2].

Classification is a process of distinguishing a class with other classes or predicting a data that its class does not recognize by using a model. The Convolutional Neural Network (CNN) is a method of Deep Learning classification with the ability to recognize predictive information of an object in various positions and has high accuracy in recognizing imagery. The way CNN mimics the human visual cortex in recognizing imagery, makes CNN a similar capability to humans in certain data [3].

Research on classifications has been conducted in many different studies in various countries on diverse objects. This research is about the search process of network architecture model that can classify the image of Pandawa figures. Therefore, the research is expected to improve various other research related to wayang classification.
2. Methodology

Table 1 shows the steps that are implemented while conducting research. Compile the research phase can simplify the implementation of research.

| No | Research Phase         | Description                                                                                                                                 |
|----|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Literary studies       | The first stage is studying the theories related to research in both the related research, methods, research objects, and other things through books, journals, and trustworthy webpages |
| 2  | Data collection        | The second stage is the collection of data that is collecting information in detail about the research object to be used, namely the image of five Pandawa figures. Once accumulated completely then the image background is edited first to white before use in the experiment |
| 3  | Implementation         | The third stage is to build the program and then implement it and do some experiments to find a good network architecture to classify the data. Then test using test data |
| 4  | Discussion of results  | The fourth stage is to describe in detail what results from the experiments that have been conducted while conducting the research. Then look for the level of accuracy gained |
| 5  | Drawing conclusion     | The final stage in this study is to draw conclusions from the overall research process and results obtained                                      |

2.1. Wayang

Wayang is a mock doll made of animal skin sculptures or wooden carvings used to portray a character in the traditional drama [4]. The origin of Wayang name originated from puppet show producing Shadows. In the past Awayang or Hawayang has the meaning of showing shadows [5].

2.2. Classification

Classification is a process of searching a model to distinguish a class of data that one with a class of other data, as well as data that does not have a class. Machine Learning is a computing method that works based on historical data information to improve the ability to predict and classify. The Convolutional Neural Network or frequently abbreviated CNN is one of the methods in Machine Learning is the development of multilayer perceptrons, which are used to process two-dimensional data [6].

2.3. Convolutional Neural Network

In a CNN architecture there are two main stages of feature learning and classification [7]. Figure 1 shows the example architecture of CNN. Based on Figure 1, the first stage in CNN is the convolution by using a certain size and base, and then the result will be subject to the ReLU activation function. After being charged the activation function then through the pooling process. These stages are repeated several times which are then generated feature map. Featured map will go through the process of flattening before it can be used as input in fully connected. After going through the fully connected layer will then be charged Softmax classifier which then output result is the class of input data.
2.4. RelU Activation Function
The RelU operation is an operation that has the purpose of introducing nonlinearity and improving the performance of a model. Figure 2 displays a graph of the calculation result of the RelU activation function. The RelU activation function creates a constraint at number 0, if the input value is less than 0 then the output is 0 and if the input value is more or equal to 0 then the resulting output is the input value itself [8].

![RelU Graph](image)

**Figure 2.** Graph result calculation of RelU activation function

2.5. Max Pooling
The Pooling operation used in this study is a Max Pooling operation, where the value taken is the maximum value in an area of size a x a [6]. Figure 3 shows the example of Max Pooling operation. In the Figure 3 there is a matrix of 4 x 4 which is subject to max pooling operation with a 2 x 2 pooling mask or filter with a stride worth 2. Calculations start from the top left side to the right with a shift as far as 2 pixels horizontally then vertically.

![Max Pooling Example](image)

**Figure 3.** Example of Max Pooling operation
2.6. Adam Optimization Algorithm
Adam Optimization Algorithm is an optimization algorithm for renewing weights in neural networks. Adam has a prolonged adaptive moment estimation. This algorithm can work efficiently in resolving deep learning problems that use large amounts of data. [10]

2.7. Softmax Classifier
Softmax classifier is the activation function used to classify data consisting of more than two classes [9]. The Softmax classifier can provide output with a better probability interpretation value compared to other classification algorithms. Probability values for the entire class can also be counted.

3. Results and Discussion
Figure 4 shows some puppet imagery data used in this research. In this study used 1000 datasets consisting of wayang images of Yudhistira, Bima, Arjuna, Nakula and Sadewa for each of the characters there are 200 datasets. The Dataset used is 100 × 100. Based on the Zufar research, the larger the size of the image used will be the easier the program recognizes the imagery, as more information is obtained during the feature learning [11]. The training data is used 80% of the total data and 20% of the data is used as test data. From previous studies, it was also mentioned that the amount of data that is used can affect the accuracy of the classification results, the amount of training data suggested between 70%, 80% and 90% [8].

![Figure 4. Wayang Image Data](image)

Appropriate network architectures are required with the data used to obtain good accuracy results. Based on the research results of several experiments that have been carried out so CNN acquired the network architecture by using 3 layer convolution using the ReLU activation function and on the pooling layer using Max Pooling operation. It is also used in 3 hidden layers using the ReLU activation function as well as 1 layer output for classification using the Softmax Classifier.

Figure 5 shows the CNN architecture used in the research. CNN's network architecture used has a 100 × 100 input size, then on the first convolution layer used a 3 × 3 kernel with the number of filters used is 16, on the first pooling layer used max pooling operation. The second convolution Layer uses a 3 × 3 kernel with the number of filters used is 32 pieces, then in the second pooling layer is also used Max pooling operation. In the third convolution layer is also used the same kernel size but the number of filters used is 64 pieces, in the third layer pooling also used max pooling operation. After pooling
the third layer results from the extraction of the feature then it is converted into single vector data via flatten operation. After going through the process, data flattening will be processed on the 3 hidden layers which each have a number of neurons as much as 32, 16 and 8 units. Each layer also uses a dropout value of 0.1 to reduce overfitting. Then the last one on the output layer is 5 units of neurons according to the number of data classes.

![Network Architecture Graphs Used](image)

**Figure 5.** Network Architecture Graphs Used

Table 2 shows accuracy value on changes in Epoch and Batch Size parameters in network architectures used. Conducted several experiments by changing the parameters of Epoch and Batch Size values when researching to see the highest accuracy value gained using the same network architecture.

| No | Epoch | Batch Size | Accuracy (%) |
|----|-------|------------|--------------|
| 1  | 10    | 16         | 87.75        |
| 2  | 10    | 32         | 83.75        |
| 3  | 10    | 64         | 55.25        |
| 4  | 20    | 16         | 91.00        |
| 5  | 20    | 32         | 81.11        |
| 6  | 20    | 64         | 82.12        |
| 7  | 20    | 128        | 79.37        |
| 8  | 100   | 64         | 97.88        |
|    | Average percentage | 82.28       |
Level of accuracy in trials 1 to 3 with epoch value 10, the larger the batch size the smaller the level of accuracy gained. The level of accuracy in trials 4 to 7 with epoch value 20 has a fairly high level of accuracy on with the use of a batch size value of 16. But in the use of the batch size value 128, the level of accuracy gained decreased but still good enough is 79.37\%. From here then attempted 8 by using an epoch value of 100 and a batch size of 64, then the level of accuracy produced is very good i.e. 97.88\%.

Figure 6 shows graph of accuracy value against Epoch and Batch size values. Graph of the accuracy value on each Epoch when the research process can be used to see which network architecture has a stable chart [12].

Figure 6. Graph Of Accuracy Value Against Epoch and Batch Size
Figure 7. Graph Of Accuracy Value Against Epoch and Batch Size (continuation)

The Blue line indicates the level of accuracy in the training process, while the yellow line indicates the level of accuracy in the testing process. The level of accuracy in trial 1 decreased on epoch 10. In the test 2 levels of accuracy when the training process improves well, but the level of accuracy in the testing process decreases. Trial 3 has a good level of accuracy chart, but due to the small epoch value so the level of accuracy is finally lacking. At the test 4 the level of accuracy obtained is also very good that is above 90%, but in the final epoch the accuracy level decreases. Then in the 5, 6 and 7 trials, the final accuracy level obtained is quite good, but from the graphics can be seen the level of accuracy that is gained significantly up downward. From trial 3, then the epoch value used is added to 100 for the trial 8. It produces an excellent level of accuracy and the resulting graphics are quite stable and do not experience significant increases or decreases in accuracy.

Table 3. Classification Results in Test Data

| Classification | Result | Total | Successful (%) |
|----------------|--------|-------|----------------|
| Yudhistira     | 39     | 0     | 1              | 0 | 0 | 40 | 97.5% |
| Bima           | 0      | 40    | 0              | 0 | 0 | 40 | 100%  |
| Arjuna         | 0      | 0     | 39             | 1 | 0 | 40 | 97.5% |
| Nakula         | 0      | 0     | 0              | 37 | 3 | 40 | 92.5% |
| Sadewa         | 0      | 0     | 2              | 38 | 40 | 95% |
| Average        |        |       |                |   |   |    | 96.5% |

Table 3 shows the classification results in test data. Based on experiments implemented, the best model is the network architecture with the value of Epoch 100 and Batch Size 64 on trial 8. So, for the classification of test data used models on the trial 8. Based on the Table 3, the model can precisely
classify the test data, which is 39 dataset of Yudhistira, 40 dataset of Bima, 39 dataset of Arjuna, 37 dataset of Nakula, and 38 dataset of Sadewa.

4. Conclusion
Based on the results of the research in classifying the image of Pandawa figures using the method Convolutional Neural Network (CNN), Epoch and Batch Size values are influential in the value of accuracy during classification. The network architecture with Epoch and Batch Size values of 100 and 64 is the best model that can be used to classify 1000 datasets with 80% of training data and 20% test data. Has an accuracy percentage of 97.88% during training and 96.5% during testing.

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