

Classification of Character Types of Wayang Kulit Using Extreme Learning Machine Algorithm

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Abstract—Wayang Kulit, which is an original Indonesian culture, is conditioned by the meaning of life in every performance. However, Wayang Kulit is currently less popular among young people due to a lack of understanding of the art of Wayang Kulit performance. To be able to provide knowledge to the younger generation about Wayang Kulit, one of which is by introducing the characters that exist in Wayang Kulit performances. This study aims to build an image classification system for Wayang Kulit characters by applying the neural network method using Extreme Learning Machine (ELM) and morphological feature extraction. Morphological feature extraction provides information about the shape characteristics of objects present in the image which are then used for input in the classification process. The Extreme Learning Machine (ELM) method may arbitrarily establish the weight value between the input neurons and the hidden layer during the classification step, resulting in a quicker learning pattern. Based on the test results using the confusion matrix, the accuracy value is calculated to get a value of 81%.

Keywords: Artificial Neural Networks; Extreme Learning Machines; ELM; Morphological Feature Extraction; Wayang Kulit

1. INTRODUCTION

Wayang Kulit art has been designated by UNESCO as Indonesia's first intangible cultural heritage in the category of Representative List of the Intangible Cultural Heritage of Humanity in 2003. [1]. Wayang Kulit is an art form using the form of mythological characters, which are usually made using dried sheets of animal (buffalo or cow) skin. [2]. In Wayang Kulit performance art, it is played by a puppeteer who has the role of director and leader of the course of the show, as well as playing all the movements of the puppet characters shown. Wayang performances as a cultural art always display abilities as a spectacle, order, and guidance. However, Wayang Kulit, which is an original Indonesian culture that requires the meaning of life in every performance, has started to become unpopular among young people. This can be seen in the data from the Central Bureau of Statistics for Social and Culture in 2021, showing a decrease of 23.06% for children aged 5 years and over who saw art exhibitions from 2018 to 2021 [3]. The indigenous generation of the area shows indifference to the existing arts due to a lack of understanding and knowledge about art, especially Wayang Kulit performances [4]. To be able to provide knowledge to the younger generation about Wayang Kulit, one of which is by introducing the characters in the Wayang Kulit performances. However, the characters in Wayang Kulit are numerous and varied. Wayang kulit characters can be classified based on their images, especially their shapes. So through digital image processing, image classification can be carried out to make it easier to recognize the types of Wayang Kulit characters.

Digital image processing involves creating, processing, and analyzing images to reveal information and make them more usable [5]. Image classification is one of the uses for image processing. The technique of classifying photographs into groups based on image elements, with each group sharing the same traits, is known as image classification [6]. To categorize diverse things and make them easier to identify, image classification is useful [7]. Research related to the utilization of digital image processing in the classification and identification of images of the types of Wayang Kulit characters has been carried out by several researchers. The first research related to the classification of Wayang Kulit imagery by applying the K-Nearest Neighbor (KNN) approach. With a 77.5% accuracy rate in this investigation, the model created was able to classify Wayang patterns [8]. The Gray Level Co-occurrence Matrices (GLCM) approach is used as the feature extraction technique for texture features. Based on learning data that has a closeness value to the item, the KNN algorithm may categorize objects. However, KNN is susceptible to variables without information and has issues with outliers [9]. Subsequent research is research on the classification of Wayang characters using the Support Vector Machine (SVM) approach and texture feature extraction with Gray Level Co-occurrence Matrices (GLCM) [10]. With an accuracy of 83.2%, this study's classification success rate is high. The SVM algorithm, which divides the best hyperplane into two classes, is effective in simple class situations, but less so in complex class cases [11]. Another study is the classification of Wayang imagery using the Multi-Layer Perceptron (MLP) method [12]. This study uses textural features in the feature extraction procedure, just like earlier studies. The accuracy test results demonstrate that the model can successfully classify at 73.4%. Artificial neural networks can recognize patterns and translate a single input into an output after being trained depending on that training by emulating how human nerves function [13]. However, because the weight value and bias value of each epoch must be updated for the MLP artificial neural network, the learning process takes longer [14].

The difference between this research and previous research is that this research implements the Extreme Learning Machine (ELM) algorithm. The Single Hidden Layer Feedforward Neural Network, which is a type of artificial neural network used in the ELM method, has one hidden layer [15]. When compared to traditional neural network methodologies like backpropagation, this method has advantages in terms of learning speed that are more ideal [16]. The ELM algorithm was created to address issues with feedforward artificial neural networks' learning rates. The feedforward neural network's learning process is long since training is based on a slow gradient and computations are made iteratively across all of the current parameters. While in the ELM network, each parameter, including the hidden and input weights, can be chosen at random, resulting in a significantly faster learning rate and better-performing generalizations [17]. Previous research also shows that the ELM algorithm can be applied to digital image processing and get good results [18]–[20]. To supplement the ELM method, this study also employs morphological feature extraction, which uses feature extraction based on a feature's shape. Furthermore, morphological features were used in this study to derive shapes. This is done because wayang kulit can be identified based on its shape. For the type of wayang character used in this study, namely Pandawa Lima. Pandawa Lima is a popular figure in Wayang Kulit, which refers to the five brothers found in the story of the Mahabharata.

Based on the previous explanation, this study aims to build an image classification system for Wayang Kulit characters by applying the neural network method using the Extreme Learning Machine (ELM). To support the ELM algorithm, morphological feature extraction is used with the parameters area, perimeter, eccentricity, major axis length, and minor axis length. The classification procedure uses the feature extraction's information about the shape features of the image's items as its input. The Extreme Learning Machine (ELM) algorithm can arbitrarily determine the weight value between the input neurons and the hidden layer during the classification step.

2. RESEARCH METHODOLOGY

2.1 Research Stages

It is vital to create structured and planned research stages in order to conduct research that can be done correctly and in accordance with the objectives. The steps in conducting research on image classification of Wayang Kulit characters using the Extreme Learning Machine (ELM) algorithm are presented in Figure 1.

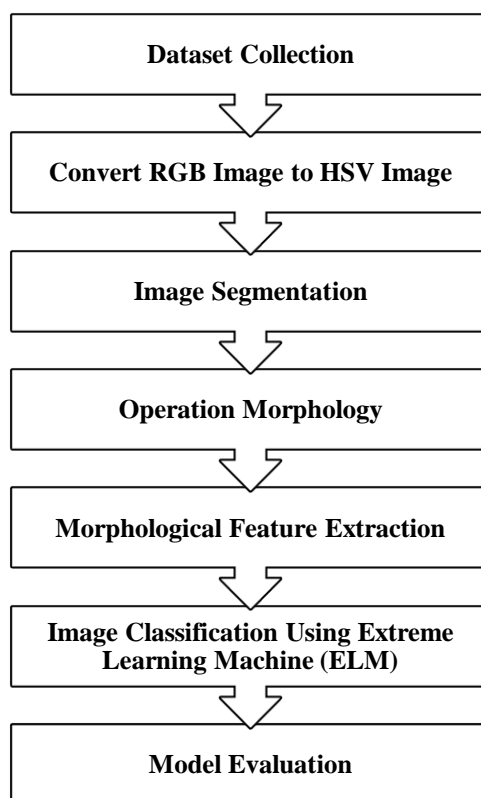


Figure 1. Research Stages

Based on Figure 1, you can see the phases in conducting the research. The following is a more detailed description of the stages of the research carried out:

a. Dataset Collection

Image data is gathered at this point and used as a dataset. The availability of datasets affects a model's performance, hence datasets are a crucial component in image processing [21], [22]. The dataset used is taken

from the Kaggle website with the following link <https://www.kaggle.com/datasets/ryandargunawan7/11-tipe-wayang-indonesia>. The types of Wayang Kulit characters used are the Pandawa Lima characters, including: Yudistira, Arjuna, Werkudara, Nakula and Sadewa. The total image data that has been collected is 500 images, with a percentage of 60% for training data and 40% for testing data. So that the training data is 300 images and the training data is 200 images.

b. Convert RGB Image to HSV Image

Images containing the RGB color space are typically converted to the Hue, Saturation, and Value, or HSV, color space first to facilitate image processing. When it comes to capturing color, the HSV color model offers an overview of shading that is comparable to human sensibility [23]. The segmentation process may be sped up by transforming RGB photographs into HSV images, which will result in images with HSV colors that can be observed on segmented objects.

c. Image Segmentation

At this point, the picture is helpful for separating items from their surroundings. It will then be divided depending on the limits of its area during object image segmentation so that it can be distinguished from the backdrop. The image will now be converted to a binary image, so the desired item will receive a value of 1, and the backdrop will receive a value of 0 [24]. In this work, threshold image segmentation methodology was used. The goal of this strategy is to find an acceptable threshold value that will make it simpler to separate items in the image [25]. Consequently, the thresholding result's output image is a binary image.

d. Operation Morphology

The objective at this point is to enhance the image segmentation findings so that the segmented item is shown clearly. Morphological procedures are often used with binary images to enhance segmentation outcomes [26]. There are many different kinds of morphological procedures; in this research, filling holes, opening operations, and closure operations were employed. The whole area is filled with a value of 1 using the filling holes morphological procedure, where the reference is based on the pixel value. Smoothing lines that create things, removing narrow components, and removing thin protrusions are all done by opening morphological processes. The closure morphological process eliminates the holes, rejects the pieces, and fills the gaps in the lines in the meanwhile.

e. Morphological Feature Extraction

Feature extraction is one method for obtaining traits that are used to distinguish one item from another [27]. The collected features are subsequently put to use as data that may describe items that the categorization method will handle. Area, perimeter, eccentricity, main axis length, and minor axis length are the parameters employed in this study's morphological feature extraction. The number of pixels that make up an item in a picture may be used to calculate its area. The number of pixels around an item may be used to calculate its perimeter. The diameter of an area is thus the major axis length, and the smallest diameter of an area is the minor axis length. Other morphological traits, such as eccentricity, may be determined based on the main and minor axes. The length difference between the main and minor axes is what determines eccentricity.

f. Image Classification Using Extreme Learning Machine (ELM)

Artificial neural networks are utilized in the classification step as part of the Extreme Learning Machine (ELM) method. The Single Hidden Layer Feedforward Neural Network, which is a form of artificial neural network used in the ELM technique, contains one hidden layer [15]. When compared to traditional neural network methodologies like backpropagation, this method provides benefits in terms of learning speed that are more ideal. [16]. The ELM algorithm was created to address issues with feedforward artificial neural networks' learning rates..

g. Model Evaluation

This phase attempts to evaluate the effectiveness of the created model [28]. Calculate the precision, recall, and accuracy values in order to evaluate the constructed model using the confusion matrix.

2.2 Extreme Learning Machine (ELM) Algorithm

A hidden layer is used by the Extreme Learning Machine (ELM), a sort of artificial neural network. ELM is a technique for learning artificial neural networks that was developed as a result of the use of single-layer feedforward neural networks [15]. The ELM algorithm was created to address issues with feedforward artificial neural networks' learning rates [17]. The learning process is long in the feedforward neural network because training is based on a slow gradient and computations are made recursively over all of the current parameters. While in the ELM network, each parameter, including the hidden and input weights, may be chosen at random, resulting in a significantly quicker learning rate and better-performing generalizations [17]. Figure 2 provides a representation of the ELM method architecture.

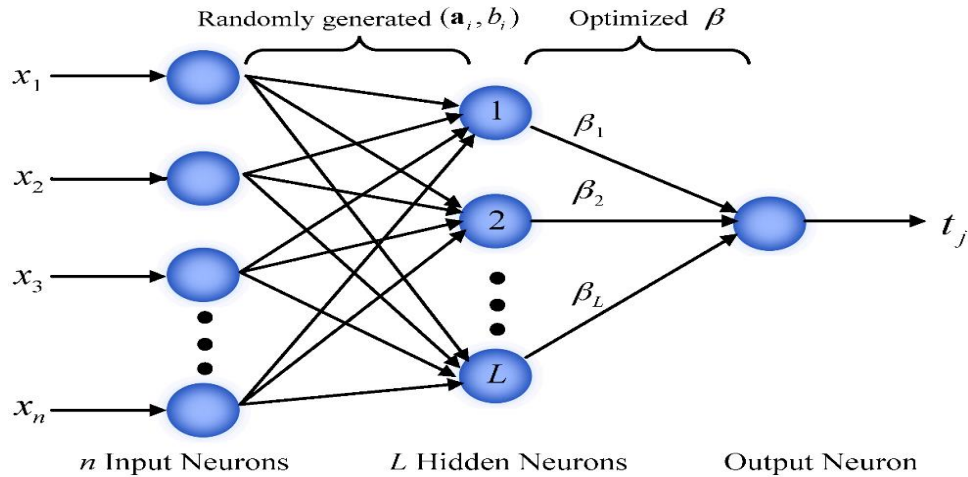


Figure 2. Artificial Neural Network Architecture Using Extreme Learning Machine (ELM)

The Extreme Learning Machine (ELM) is a type of artificial neural network that utilizes a hidden layer. As a result, after the network has been trained, it can do data categorization, which is faster than utilizing an analytical model to solve a problem [29]. This demonstrates that the ELM neural network technique outperforms traditional learning methods in terms of computing performance [14]. Compared to feedforward neural networks, the ELM algorithm uses a distinct mathematical strategy. This is due to the ELM method's less complex computations [18]. For N with different number of inputs and output targets, like (x_i, t_i) where $x_i = [x_{i1}, x_{i2}, \dots, x_{in}]^T \in R^n$ and $t_i = [t_{i1}, t_{i2}, \dots, t_{im}]^T \in R^m$ then the number of hidden layers is \tilde{N} and the activation function $g(x)$ dapat diselesaikan can be solved using equation (7).

$$\sum_{i=1}^{\tilde{N}} \beta_i g_i(x_{ij}) = \sum_{i=1}^{\tilde{N}} \beta_i g_i(w_i \cdot x_j + b_i) = o_j \quad (7)$$

where w_i denotes the weight vector for connecting between the 1st hidden node and the input node, β_i denotes the weight vector for connecting between the 1st hidden node and the output node, b_i denotes the threshold value at the hidden node, while $w_i \cdot x_j$ denotes the inner product of the w_i and x_j values.

Then, equation (7) is simplified to equation (8).

$$H\beta = T \quad (8)$$

where H is the hidden layer input matrix, while T is the target matrix.

In an artificial neural network using the ELM method, the input weight and hidden values can be obtained by doing random, then the output weight associated with the hidden layer can be obtained using equation (9).

$$\beta = H \dagger T \quad (9)$$

where β is the output weight, H is the hidden layer input matrix, while T is the target matrix.

2.3 Model Evaluation

Measurements of the created model's performance are made during the evaluation step [30]. Calculate the precision, recall, and accuracy values in order to assess the constructed model using the confusion matrix [31]. The degree of accuracy between the intended information and the system's findings is known as precision. The success of the system in retrieving information is then measured by recall. While accuracy measures how well the categorization findings correspond to reality. Precision, recall, and accuracy can be found using equations (10), (11) and (12).

$$Precision = \frac{TP}{TP + FP} \quad (10)$$

$$Recall = \frac{TP}{TP + FN} \quad (11)$$






$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN} \quad (12)$$

where, TP (True Positive) shows positive data that is correctly classified. Then, TN (True Negative) is negative data that is classified correctly. In contrast to FP (False Positive) which shows negative data but is classified as positive data. Meanwhile, FN (False Negative) shows positive data but is classified as negative data.

3. RESULT AND DISCUSSION

In this study, the implementation of the artificial neural network method uses the Extreme Learning Machine (ELM) to classify the types of Wayang Kulit characters. The initial stage starts with gathering datasets that will be utilized as training and testing data in the future. Making a collection of picture data, also known as a dataset, is the first step in classifying images of different sorts of Wayang Kulit figures. The dataset used is taken from the Kaggle website with the following link: <https://www.kaggle.com/datasets/ryandargunawan7/11-tipe-wayang-indonesia>. The types of shadow puppet characters used are the Pandawa Lima figures, namely: Yudistira, Arjuna, Werkudara, Nakula and Sadewa. The total image data that has been collected is 500 images. Based on this dataset, 300 image data are used for training to design models, where in each class there are 60 images. The sample dataset used is in the form of images of the Wayang Kulit Pandawa Lima characters, which can be seen in Table 1.

Table 1. Dataset Image Samples

Wayang Kulit Characters	Image Sample
Yudistira	
Arjuna	
Werkudara	
Nakula	
Sadewa	

The created model is then put into use in the MATLAB program for both training and testing. Starting with the conversion of RGB images to HSV images, the constructed model is trained. The goal of this procedure is to simplify regional segmentation. This is due to the HSV image's coloring nature, which is identical to human perception when it comes to capturing color. In order to make picture segmentation simpler at this step, it will output images with HSV colors that concentrate on objects. Figure 3 displays sample Wayang Kulit character pictures that were created after the conversion of RGB images to HSV images.

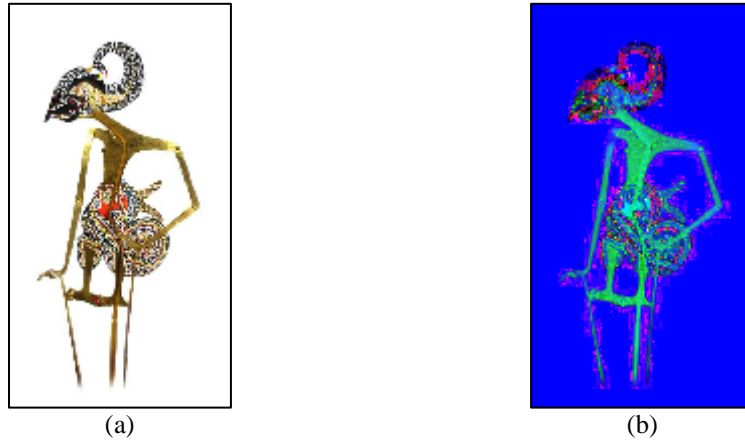


Figure 3. (a) Original Image and (b) Converted Image to HSV

The results of the RGB to HSV conversion, which is done to make the segmentation procedure easier, are shown in Figure 3(b). The Thresholding approach is then used to segment images in the next step. In order to distinguish the picture's foregrounds and backgrounds, it will now be transformed to a binary image. Figure 4 displays the outcomes of image segmentation on the picture of the Wayang Kulit characters.

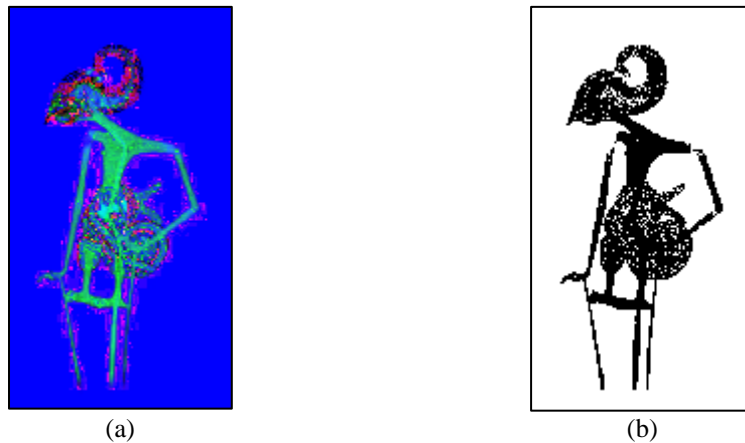


Figure 4. (a) HSV Image and (b) Segmented Image

In Figure 4 (b) it can be seen that the image has been segmented through a thresholding technique, where the image is clearly visible between the background and the foreground. However, by clearly displaying the form of the item to be identified, the results of this segmentation need to be enhanced in order to assist the feature extraction process. Therefore, the next step is to use morphological techniques to enhance the outcomes of picture segmentation. Filling holes, opening, and shutting procedures are some of the morphological operations used. Figure 5 displays the outcomes of image morphological operations performed on the picture of the Wayang Kulit characters.

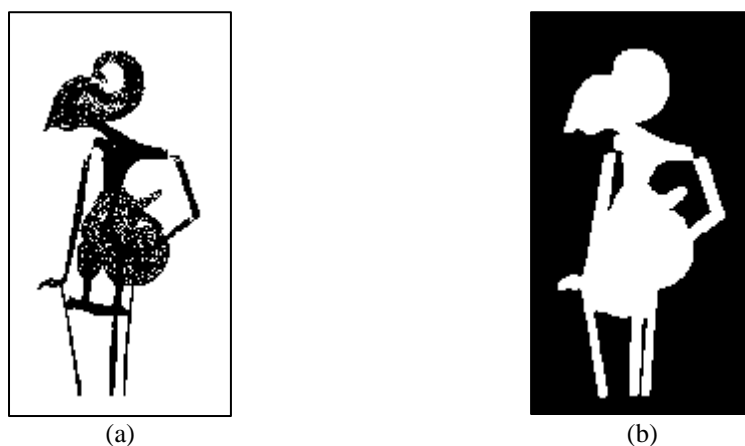


Figure 5. (a) Segmented Image and (b) Morphological Operation Image

Figure 5 (b) shows that the image has been subjected to morphological operations using the filling holes operation, where the object to be classified is white. This is done to make it easier to perform shape feature extraction.

Shape feature extraction can recognize the characteristics of an object based on its shape. The feature extraction that is applied is morphological features, which will be calculated through parameters including area, perimeter, eccentricity, major axis length, and minor axis length. Sample results of parameter values on morphological features are presented in Figure 6.

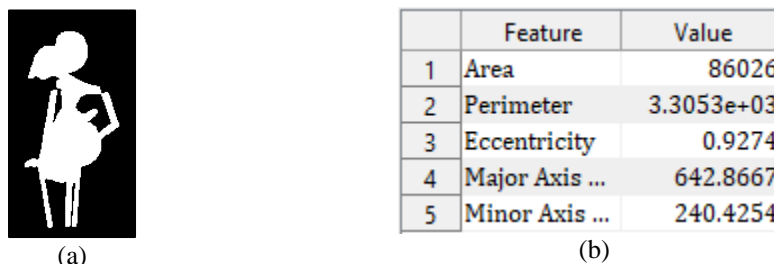


Figure 6. Morphological Operational Image and (b) Value of Each Parameter on Morphological Characteristics

Figure 6 (b) shows the result of the value of each parameter in the morphological feature extraction that represents the shape of the image of the Wayang Kulit character that will be classified. Furthermore, the morphological feature extraction parameter values are used as a reference for the Extreme Learning Machine (ELM) algorithm to determine groups of objects that have the same characteristics. The ELM algorithm has a network architecture by determining random weighting to determine the input neurons and hidden layer. In this way, the ELM algorithm has a faster computational process. The architecture of the ELM algorithm takes into account the feed-forward pass to determine the input layer and the hidden layer. In training for determining weights, this algorithm processes them in the hidden layer and output layer. The stages in the classification process carried out by the ELM algorithm are shown in the following process:

- Input : Input pattern (x_i, t_i) , where $x_i = [x_{i1}, x_{i2}, \dots, x_{in}]^T \in R^n$ and $t_i = [t_{i1}, t_{i2}, \dots, t_{in}]^T \in R^m$
- Output : Input weight (w_i) , output weight (β_i) and hidden bias (b_i)
- ELM Algorithm Phase :
 - Phase 1 : Find the value that serves as the activation $(g(x))$ and all hidden nodes (\tilde{N})
 - Phase 2 : Calculating random values from input weights (w_i) and hidden bias (b_i)
 - Phase 3 : Form an output matrix (H) on the hidden layer
 - Phase 4 : Determine the resulting output weight (β) by calculating it using $\beta = H \dagger T$

Furthermore, the developed ELM neural network model is implemented in MATLAB software. To test the model and make it easier to use, the developed model is implemented in MATLAB software, and then an application for the classification of the types of Wayang Kulit characters is built in the form of a GUI. Figure 7 below is the interface display of the Wayang Kulit character classification system.

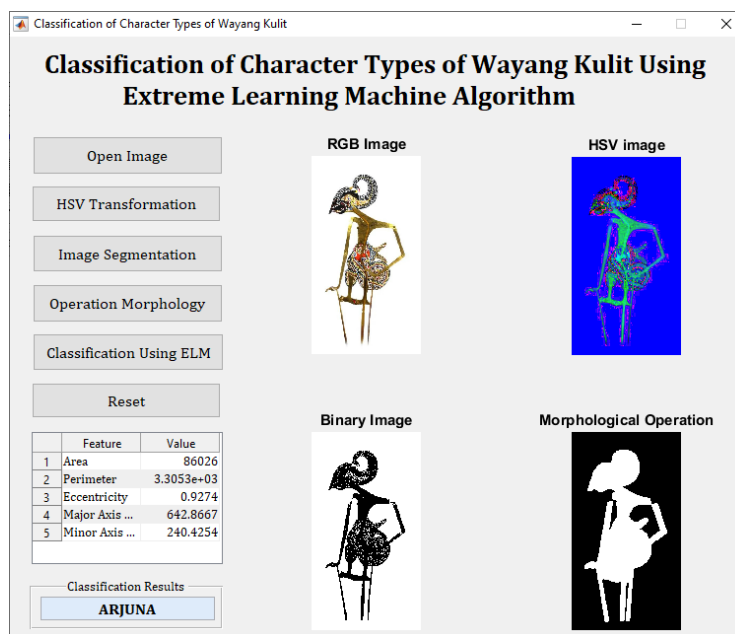


Figure 7. Display of the Wayang Kulit Character Application Interface

Furthermore, the model that has been built into the application of the classification of the types of Wayang Kulit characters will be evaluated so that its performance can be measured. The image data for the type of Wayang

Kulit characters used as test data is 200 images. The test is carried out by comparing the results of the classification carried out by the model with the existing facts. The confusion matrix is then used to calculate the values of TP (True Positive), TN (True Negative), FP (False Positive), and FN (False Negative) based on the test results. The results of the confusion matrix from the tests carried out can be seen in Figure 8.

		Truth data					Classification overall
		Yudistira	Arjuna	Werkudara	Nakula	Sadewa	
Classifier results	Yudistira	34	2	1	2	2	41
	Arjuna	3	32	1	2	2	40
	Werkudara	2	1	36	1	2	42
	Nakula	1	2	1	30	5	39
	Sadewa	1	2	1	4	30	38
	Truth overall	41	39	40	39	41	200

Figure 8. Confusion Matrix Results

Figure 8 illustrates the confusion matrix's findings. The results are then used to obtain precision, recall, and accuracy values, whose results are presented in Table 2.

Table 2. Test Results

Class Name	Precision	Recall	Accuracy
Yudistira	0.8293	0.8293	
Arjuna	0.8000	0.8205	
Werkudara	0.8571	0.9000	0.8100
Nakula	0.7692	0.7692	
Sadewa	0.7895	0.7317	

In Table 2, it can be seen that the accuracy value of all test cases shows a value of 0.8100, or 81%. Furthermore, these results are then converted into assessment categories with the following references: Very poor, if you get a score of less than 40%; Less good, with a value of 40% to 55%; Fairly good, with a value of 56% to 75%; and Good, with a value of 76% to 100%. [32]. Based on these categories, the developed model is included in the good category. If it is related to previous research on the classification of the character image of Wayang Kulit characters, the results of this accuracy are higher than studies using the KNN method [8] which produces an accuracy of 77.5%, and research using the Multi-Layer Perceptron (MLP) method [12] which produces an accuracy of 73.4%. However, this research is not higher than research using the Support Vector Machine (SVM) approach [10] which produces an accuracy of 83.2%. In this study, the Wayang Kulit character classes used were Arjuna, Batara Wisnu, Gareng, Werkudara, and Yudistira. In the research conducted by Wayag Kulit, the Five Pandavas were used, namely Yudistira, Arjuna, Werkudara, Nakula, and Sadewa. These characters have a similar form, especially in the Nakula and Sadewa classes. This is because Nakula and Sadewa are Wayang Kulit characters who are told as twins. This can be seen from the results of the classes with the lowest precision, namely the Nakula class with a value of 0.7692, and the lowest recall, namely the Sadewa class with a value of 0.7317. In addition, the experimental results show that the error rate reaches 19%, this can occur due to several factors, including: 1) The ELM neural network algorithm in determining the initial neuron weights is carried out randomly, this causes the resulting values to be different. ; 2) There are classes that have almost the same characteristics, so they cannot only use shape feature extraction but can use other features such as color and texture; 3) For images with various perspectives and backgrounds, it is difficult for the model to classify, so it needs pre-processing to get the ideal dataset; 4) The number of datasets used is still relatively small, so it requires additional datasets so that the learning patterns carried out are more optimal.

4. CONCLUSION

This research classifies image types of Wayang Kulit characters through the application of the Extreme Learning Machine (ELM) artificial neural network method. The feature extraction used in this research is shape feature extraction using morphological features. The metrics area, perimeter, eccentricity, major axis length, and minor axis length are employed in the extraction of morphological features. The classification procedure uses the feature extraction's information about the shape features of the image's items as its input. The Extreme Learning Machine (ELM) method may randomly select the weight value between the input neurons and the hidden layer during the classification stage, resulting in a quicker learning pattern. Based on the accuracy results, it gets a value of 81% and is included in the good category. However, for further research, there are several suggestions for improvements, including the need to combine with other algorithms in order to overcome the determination of the initial neuronal

weights, which are carried out randomly, so that learning can be maximized. Additionally, it may use deep learning to get around different learning patterns. It is not enough to rely on feature extraction only on its shape, it is necessary to implement other possible features. Large volumes of data must be used in order to get the best learning results.

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