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Color Clustering in the Metal Inscription Images Using ANFIS Filter

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Abstrak

Prasasti kuno merupakan catatan sejarah masa lalu yang dibuat pada media batu atau logam. Saat ini banyak prasasti kuno yang rusak karena terlalu lama terkubur di dalam tanah. Penelitian ini merupakan langkah awal untuk memperbaiki tulisan yang rusak dengan menggunakan pengolahan citra. Upaya restorasi menggunakan clustering warna dengan metode ANFIS merupakan tahap awal untuk melakukan segmentasi huruf pada prasasti. Hasil dari metode clustering ANFIS kemudian dibandingkan dengan spatial fuzzy clustering method (SFCM). Untuk mengukur kualitas hasil clustering kedua metode tersebut dilakukan pengukuran nilai root mean square error (RMSE). Dari pengukuran RMSE, nilai rata-rata yang diperoleh untuk pengukuran clustering dengan metode ANFIS lebih kecil 21,80% dibandingkan dengan SFCM. Ini berarti ada peningkatan kinerja clustering dengan metode ANFIS dibandingkan dengan SFCM.

***Kata kunci**: Prasasti logam, Clustering, CIELab, ANFIS*

Abstract

Ancient inscriptions are historical records of the past age made on stone or metal media. Currently many ancient inscriptions were damaged because it is too long buried in the ground. This research is the first step to repairing the damaged inscription using Image processing. Efforts to restorations using color clustering with ANFIS method are an early stage to perform letters segmentation in the ancient inscription. The Results of ANFIS clustering method are compared to the spatial fuzzy clustering method (SFCM). The clustering performance measurement is done by measuring root mean square error (RMSE). From RMSE measurements, the average values obtained with ANFIS clustering method is smaller 21.80% than with SFCM. This means there is an increase in clustering performance with ANFIS method compared to SFCM.

***Keywords**: Metal inscription, Clustering, CIELab, ANFIS*

1. Introduction

The inscription is one of the evidence of the important past history. Metal is a medium that is commonly used to make inscriptions on ancient kingdom era in Indonesia. For metal inscription, materials commonly used are copper and brass. In this paper, the inscription that is used as the object of research is the Adan-adan inscription, which is a royal heritage Majapahit (13 – 14 century AD). Adan-adan inscription made from copper material. The Adan-adan inscription was chosen because of an inscription plate has damaged. Damage is caused by metal inscriptions ever buried in the ground for a long time. Moist land conditions caused the inscriptions has been covered by patina. The inscription surface covered by Patina changed colors and fonts that exist on inscription. The color changes are not evenly distributed and letters in the inscription are also covered which causes much damage to the inscriptions. Adan-adan inscription sample images covered by patina can be seen in Figure 1.

ANFIS has been used in image processing by several researchers, some of them are for: image segmentation [1–4], extraction of images [5], and filtering noise in the image [6–15]. Advantages use of fuzzy systems and neural networks as a filter are because this method is based on the nonlinear approach features and this method is an adaptive function [7]. According to Yüksel [8] that perform digital image restoration, ANFIS method efficiently removes impulse noise and at the same time effectively maintains image details and texture.

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(a) (b)

Figure 1. Metal inscription
(a) with dark brown patina, (b) with green patina

Colors on the image processing are important component. Color gives an important signal in the process of clustering, classification, segmentation and recognition of an image [16–18]. A. Mojsilovic [19] analyzed the human perception of color and proposed a segmentation method based on color similarity. In addition, CIELAB color space (Lab) is a color space defined by imitating human color perception. The research of Lab color has been performed by Lei Xu for detecting license plates [20]. The result of her research was succesfull to improve the value of accuracy in detecting license plates with Lab color space compared to grayscale color. Moreover, there are several researchers who use the Lab color space to process image segmentation [16, 21, 22], and increase noise detection [23]. The combination of ANFIS and Lab color space has been performed by Abirami [24]. He used it for plant species identification in flower images based on color, texture, and shape. Pictures of flowers were segmented based on color using a K-means clustering. To perform color feature extraction, he used layer a* and b* in the Lab color space.

In a previous research we perform clustering using spatial fuzzy clustering method (SFCM). The method we used is based on the method used by Bing Nan Li [25]. Results obtained with SFCM were good if there is a shadow on the letters carved. The shadow color that contrast (darker) with the inscriptions plate color can be easily detected. Nevertheless, the color of letters carved in the inscription is almost equal with the inscriptions plate color [26], that can not be detected by SFCM method. With ANFIS method, color clustering can be done to detect the letters carved on the inscription better than SFCM.

2. Color Clustering with ANFIS Filter

The method used in this research consisted of two stages. The first stage, the image in the RGB space colour is converted into the Lab color space. Next, the images in the color space L*, a*, and b*, and prediction image. Then it will become input for ANFIS. Figure prediction is a synthesis of the results of image clustering image inscription expected. FIS structure used is the Sugeno type. To generate the FIS rules, used fuzzy c-means (FCM) clustering. The use of FCM with consideration that the data can be incorporated into a number of clusters with different membership levels. This is because the difference in color between the scratch letters and inscriptions plate insignificant. Diagram Block of the proposed method is illustrated in Figure 2.

2.1. CIELab Color Space

CIELAB color space (Lab) is a uniform perception color model in which the L^* component is a color model for intensity perception of light, while a^* and b^* are the components number of colors displayed [21]. With a^* is red and green components, and b^* is the yellow and blue color components. To perform the conversion from RGB color space to Lab color space is used transitional space, CIEXYZ (XYZ) [16, 27]. XYZ color space is the precursor of the Lab color space, XYZ values are defined to represent the red, green, and blue. To convert RGB to XYZ color used equation (1).

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.6070 & 0.1734 & 0.2000 \\ 0.2990 & 0.5864 & 0.1146 \\ 0.0000 & 0.0661 & 1.1175 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

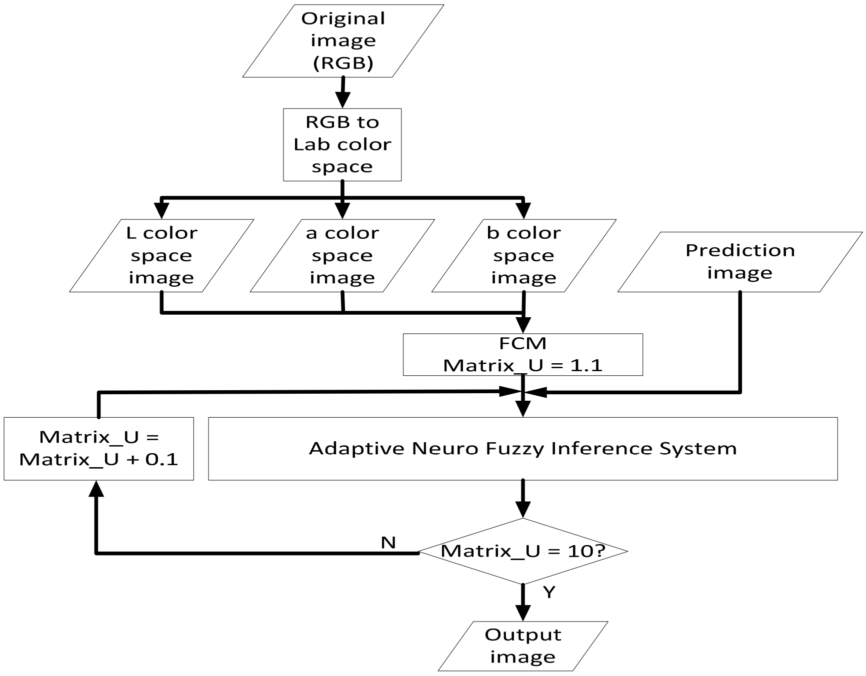


Figure 2. Diagram block of the proposed ANFIS color filter

Where, the value of X, Y, and Z, were converted to color components L^*, a^*, and b^*, using equation (2).

$$L^* = \begin{cases} 116 \times f\left(\frac{Y}{Y_n}\right) - 16, & \text{for } \frac{Y}{Y_n} \le 0.008856 \\ 903.3 \times f\left(\frac{Y}{Y_n}\right), & \text{others} \end{cases}$$

$$a^* = 500 \times \left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right) \right], \qquad b^* = 200 \times \left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right) \right] \tag{2}$$

where

$$f\left(\frac{A}{A_n}\right) = \begin{cases} \sqrt[3]{\frac{A}{A_n}}, & \text{for } \frac{A}{A_n} > 0.008856 \\ 7.787\left(\frac{A}{A_n}\right), & \text{for } \frac{A}{A_n} \le 0.008856 \end{cases} \tag{3}$$

Where A = X, Y, Z, and A_n = X_n, Y_n, Z_n. With X_n, Y_n, and Z_n is tristimulus value or chromatis coordinat for deteremined position of white color form ilumination of picture. Tristimulus values are:

$$X_n = 1,\ Y_n = 0.98072,\ Z_n = 1.18225 \tag{4}$$

The results of the inscriptions image conversion from RGB to Lab will get three layer of image, image conversion results inscription to layer L^*, a^*, and b^*. All three layers are used as input data in ANFIS along with the clustering process the expected data image.

2.2. Prediction Image

In the process of clustering using ANFIS required prediction image is the reference for the output process. Similarly, for the purposes of testing the results of clustering using image prediction RMSE is also required. In the process of testing the prediction RMSE image is used as the reference image. Prediction images in this research were made manually. The letters contained the inscription was changed to white. While it is part of the metal plate inscriptions than letters given black. Providing a contrasting color to the image prediction aims to simplify the process of clustering.

2.3. FCM

Fuzzy C-Means Clustering (FCM) is one of the popular clustering algorithms. First introduced by Jim Bezdek [28], FCM is a development of the k-mean clustering, with the model using fuzzy clustering so that the data can be a member of any class or cluster. An image can be represented in different feature space, and classify images with FCM algorithm to group similar data points in the feature space into clusters. Output of the FCM is a row of cluster centers and the degree of membership for each data point. This information is then used to build a fuzzy inference system.

2.4. ANFIS

This research is use ANFIS method because ANFIS is an implementation of fuzzy inference system in the framework of adaptive networks. ANFIS architecture can be used to model employs a non-linear function and irregular, and can identify nonlinear components in the system [2]. From the block diagram of Figure 2, show that the use of data image in Lab color space (data input) and data image prediction (data output) as training data to build the FIS structure. Grouping the data input-output combination aims to exploit the full structure of unknown function that will be approached [29].

This research use ANFIS sugeno type and presented in Figure 3. The method uses a neural network to implement the fuzzy inference system is composed of five layers:

Layer 1: At each node *i* in this layer is an adaptive node with node function:

$$\begin{aligned} O_i^1 &= \mu A_1(L^*) \\ O_i^1 &= \mu B_1(a^*) \\ O_i^1 &= \mu C_1(b^*) \\ i &= 1,2,3,4 \end{aligned} \tag{5}$$

Where $\mu A_1(L^*)$, $\mu B_2(a^*)$, and $\mu C_1(b^*)$ are membership function that determine degree to input L^*, a^*, and b^*. In other words, O_i^1 is the membership degree of fuzzy set and determine the degree of $\mu A_1(L^*)$, $\mu B_1(a^*)$, and $\mu C_1(b^*)$ from a given input L^*, a^*, and b^*. Membership function parameters used in this layer is a Gaussian. Parameters of membership functions μF Gaussian function can be approximated by:

$$f(\mu F) = e - \frac{(\mu F - \beta)^2}{2\sigma^2} \tag{6}$$

Where $F = Ai(L^*)$, or $B_i(a^*)$, or $C_i(b^*)$, and $e \approx 2.71828$ (Euler's number). β is the midpoint of the membership function, and σ is the wide range of the membership function.

Layer 2: Every node in this layer is labeled Π, non-adaptive (fixed parameter), which has the output of the multiplication of all incoming signals.

$$O_i^2 = w_i = \mu A_i(L^*)\mu B_i(a^*)\mu C_i(b^*) \tag{7}$$

Each output node (denoted by w_i) indicate degree of activation of fuzzy rules. In general, some operators T-norm can express fuzzy logic AND can be used as the node function in this layer.

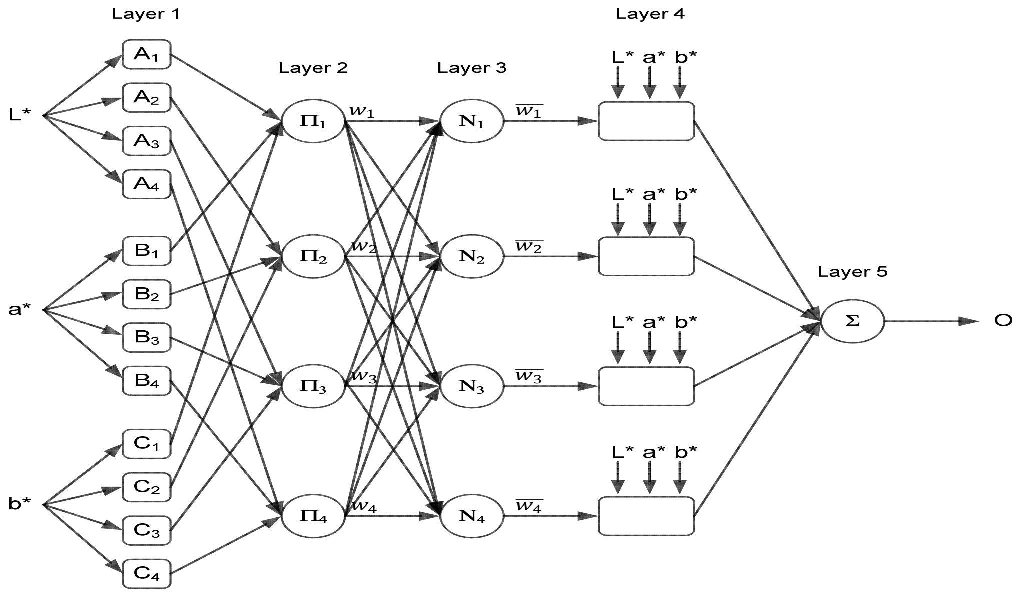


Figure 3. ANFIS structure

Layer3: Every node in this layer is labeled N, is also non-adaptive. Each node displays the degree of activation of the normalized (denoted by $\overline{w_i}$) with the form:

$$O_i^3 = \overline{w_i} = \frac{w_i}{w_1 + w_2 + w_3 + w_4} \tag{8}$$

Layer 4: Every node in this layer in the form of an adaptive node with node function:

$$O_i^4 = \overline{w_i} f_i = \overline{w_i}\left(p_i L^* + q_i a^* + r_i b^* + t\right) \tag{9}$$

Where p_i, q_i, r_i, and t is a parameter called consequent parameters.

Layer5: Single node in this layer is labeled Σ, which counts all output as the sum of all incoming signals:

$$O_i^5 = \sum_{i=1}^{4} \overline{w_i} f_i = \frac{\sum_{i=1}^{4} w_i f_i}{\sum_{i=1}^{4} w_i} \tag{10}$$

As shown in the chart Figure 4, for testing with several U values obtained smallest RMSE value 54.25, which is contained in the work for entire world U 1.6. Furthermore, this value is used in the clustering process.

2.5. Determining the value of Partition Matrix U

The values in the matrix N are crucial for convergence of the FCM group membership. For that require to use the value of exponent for the partition matrix U (U). To determine the appropriate value of U, we tested clustering using multiple values U. We use U values ranging from 1.1 to 10 with intervals of 0.1. The results of the clustering of each value of U, we measure the value of the error using the root mean square error (RMSE). RMSE measurement results we present in the graph in Figure 4.

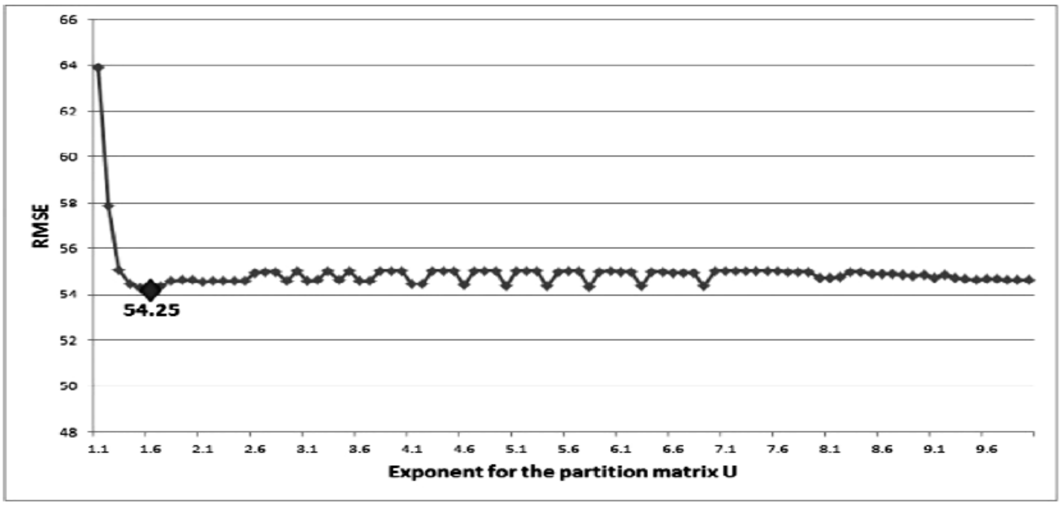
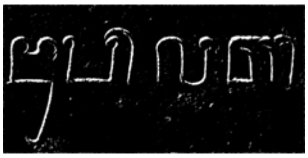
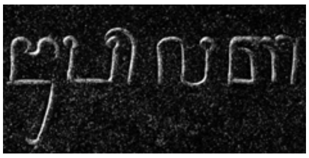
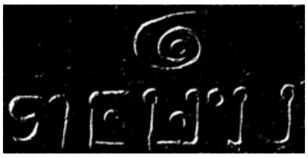
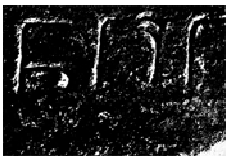
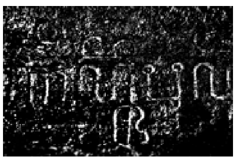
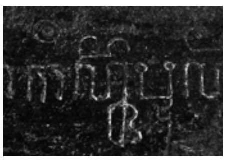


Figure 4. RMSE measurement results for several exponent values for partition matrix U

3. Results and Analysis

This research uses inscription with brown dark patina (inscriptions 1 – 3), and green patina (inscriptions 4 and 5). The result of this research will compare to spatial fuzzy clustering method (SFCM). The results of clustering using ANFIS and SFCM we present in Table 1.

Table 1.Comparison results ANFIS and SFCM

Inscription	Original Image	SFCM	ANFIS
1			
2			
3			
4			
5			

In plain view seen that the results of ANFIS have letters thicker. This indicates that ANFIS method is better to maintain the details of the letters of the inscription. Disadvantage of the ANFIS method is the amount of noise a lot. To be sure about the comparative performance of ANFIS with SFCM clustering method, we conducted performance measurements using the RMSE. RMSE is use to count average difference the square root clustering and the expected output. To calculate the values of RMSE use formula (11) and the result of RMSE can be showed in Table 2.

$$RMSE = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(U_{i,j} - V_{i,j}\right)^2} \tag{11}$$

where $U_{i,j}$ is image prediction notation and $V_{i,j}$ is image result clustering. M and N is the number of columns and rows of the image.

4. Conclusion

From the results of measurements with RMSE for clustering using ANFIS filter still needs further development. Even so this increase showed better results than the SFCM methods. From the average value of RMSE measurements obtained that RMSE value for clustering ANFIS 21.80% smaller than SFCM clustering. However, the percentage error decrease is still relatively small. Another improvement is the increase in strokes occurring letters were detected. if the SFCM method only detected shadows scratches, the ANFIS method other than shadows detected scratches are also detected scratches from letter inscription.

The next step to be done is to reduce the noise from the clustering results. The results of this process will be segmented to separate the letters from the inscription plate. The results of the segmentation are then used to identify the letters in the inscription.

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