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Identification of Authenticity and Nominal Value of Indonesia Banknotes Using Fuzzy K-Nearest Neighbor Method

Ricky Ramadhan[1], Jayanti Yusmah Sari[2], Ika Purwanti Ningrum[3]
Informatics Engineering Department, Engineering Faculty, Halu Oleo University, Kendari
rickyramadhan.p@gmail.com
jayanti@uho.ac.id
ika.purwanti.n@uho.ac.id

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Abstract-- The existence of counterfeit banknotes is often troubling the public. The solution given by the government to be careful of counterfeit banknotes is by means of 3D (seen, touched and looked at). However, this step has not been perfectly able to distinguish real banknotes and fake banknotes. So, there is a need for a system to help detect the authenticity of banknotes. Therefore, in this study a system was designed that can detect the authenticity of rupiah banknotes and its nominal value. For data acquisition, this system uses detection boxes, ultraviolet lights and smartphone cameras. As for feature extraction, this system uses segmentation methods. The segmentation method based on the threshold value is used to obtain an invisible ink pattern which is a characteristic of real banknotes along with the nominal value of the banknotes. The feature is then used in the stage of detection of banknotes authenticity using FKNN (Fuzzy K-Nearest Neighbor) method. From 24 test data, obtained an average accuracy of 96%. This shows that the system built can detect the authenticity and nominal value of the rupiah banknotes well.

Index Terms— fake banknotes, FKNN, invisible ink, real banknotes, rupiah banknotes.

I. Introduction

The rupiah banknotes counterfeiting crime has experienced a significant development. Given the very vital function of banknotes as a means of payment, the crime of counterfeiting banknotes has a major impact and is detrimental to the state. To overcome the complex problems of banknotes fraud, it is necessary to have a system that can detect the authenticity of the rupiah banknotes. On the other, the detection of the authenticity of the current rupiah banknotes is still largely dependent on human vision which is less consistent and easily fatigued [1].

In Law Article 1 paragraph 5 of Law No.7 of 2011 concerning Currency, it is stated that the Rupiah Banknotes Feature is a certain sign in every Rupiah Banknotes set with the aim of showing identity, distinguishing price or nominal value, and securing the Rupiah Banknotes from counterfeiting efforts. One characteristic of the authenticity of banknotes that is difficult to duplicate is invisible ink that can only be seen when illuminated by ultraviolet lights [2].

Research on the authenticity of banknotes by taking invisible ink has been done by Putri (2015) [3] using the template matching method and producing an accuracy of 87.5%. Based on the testing that at a distance of ±8 cm camera the system can detect all authenticity of banknotes and give satisfactory results because all original banknotes are detected "Original". while at a distance of ±7 cm and ±6 cm the system does not succeed in detecting the authenticity of banknotes. In testing with fake banknotes objects, each distance of detecting all counterfeit banknotes is false, this is because all fake banknotes do not have template images so that the maximum matching value is smaller than the maximum matching template value specified. In general, the results of these studies indicate that the system of detection of banknotes authenticity is strongly influenced by the distance/position of the camera to the position of the object. In addition, the difference in background color of the test image with the color of the template image greatly affects the similarity/value of Template Matching values. The smaller the difference, the value of the Template Matching coefficient is getting smaller even though both are different objects. Therefore, a method that is able to classify objects with features that have insignificant differences is needed.

Research on the authenticity of banknotes has also been done by Rusydi Umar [13] using the k-means clustering method without using the invisible ink feature on banknotes but using the banknotes texture feature. This study designed a detection system for the authenticity of rupiah banknotes. The characteristic extraction method with Local Binary Pattern, through the stages of introducing features in imagery such as surface texture on banknotes and classification methods using K-Means Cluster by calculating centroids from the data in each cluster using the Euclidean distance equation. The banknotes studied were IDR 50,000 and IDR 100,000, each amounting to 30 data sets for original banknotes and 20 fake banknotes data sets obtained through color copies of banknotes. Based on the simulations that have been done, to detect the authenticity of real and fake banknotes can achieve an accuracy of 96.67%.

Fuzzy K-Nearest Neighbor (FKNN) algorithm is able to consider the ambiguous nature of the features of some objects. This algorithm has been designed so that ambiguous neighbor K features do not play an important role in the classification process [4]. The basic concept of the Fuzzy K-Nearest Neighbor (FKNN) method is to provide the degree of membership as a representation of the distance of the K Nearest Neighbor feature image and its membership in several possible classes [13].

Based on the description, then in this study a system of detection authenticity and nominal value of rupiah banknotes was made by taking invisible ink on banknotes. For image acquisition of banknotes, a detection box tool is used in which there is an ultraviolet lamp which serves to maintain the distance of image acquisition so that it remains consistent and brings invisible ink from the banknotes. Furthermore, the characteristics obtained will be matched with the database using FKNN (fuzzy k-nearest neighbor) method which is expected to overcome the similarity of features in different classes so that it can improve system accuracy.

II. Literature Review

A. Rupiah Banknotes

Rupiah banknotes are banknotes in the form of sheets made of paper or other material (which resembles paper) issued by the Indonesian government, in this case Bank Indonesia, where users are protected by Law No.23 of 1999 and are legitimately used as a means of payment in Indonesia [5].

In this study, the selection of safety features in the form of invisible ink was used as a reference to check the percentage of authenticity of the banknotes. Figure 1 is a characteristic example of banknotes based on the invisible ink security feature.

Figure 1. Invisible Ink Safety Feature

B. RGB-Grayscale Image Conversion

To change a full color (RGB) image into a grayscale image (gray image), a method commonly used, namely:

$$(R+G+B)/3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Information:
R = Red pixel
G = Green pixel
B = Blue pixel

The values generated from the above equation will be inputted into each element of the basic color of the grayscale image [6].

C. Image Segmentation

Image segmentation is an image processing process that aims to separate the object area and background area so that objects are easily analyzed in order to recognize objects that involve a lot of visual perception [7].

D. Thresholding

In general, the thresholding process of grayscale images aims to produce binary images, which can be mathematically written:

$$g(x,y) = \begin{cases} 1 \text{ if } f(x,y) \geq T \\ 0 \text{ if } f(x,y) < T \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$g(x, y)$ is a binary image of a grayscale image $f(x, y)$, and T denotes a threshold value [8].

E. Fuzzy K-Nearest Neighbor

Fuzzy K-NN (FKNN) is one of the classification methods by combining Fuzzy and K-NN techniques. This method is not like other methods which in this method will explicitly predict the class followed by the test data based on the closest K ratio. The basis of the FKNN algorithm is to establish membership values as a function of vector distance from KNN and neighboring membership in possible classes. This method plays an important role in removing ambiguity in classification. In addition, an instance will have a degree of membership value in each class so that it will give more power or confidence to an instance in a class. To calculate the membership value on Fuzzy K-NN, equations (3) and (4) are used [12].

$$uij = \begin{cases} 0{,}51 + \left(\frac{nj}{n}\right) * 0{,}49, & if\ y = 1 \\ \frac{nj}{n} * 0{,}49, & if\ y \neq 1 \end{cases} \quad \text{.......(3)}$$

Information:

n_j = Number of members of class j in a data practice n

n = Number of training data used

j = Data class

$$U_i(x) = \frac{\sum_{j=1}^{k} u_{ij}(||x - x_j||^{-2/(m-1)})}{\sum_{j=1}^{k}(||x - x_j||^{-2/(m-1)})} \quad \text{............(4)}$$

Information :

Ui_j = fuzzy membership value in the example testing (x, x_j)

k = the value of the nearest neighbor

j = membership data variable test data

m = rank weight which is m>1

III. Research Methodology

This authenticity and nominal rupiah banknotes detection system was built using the Matlab R2015b application and FKNN classification method (Fuzzy K-Nearest Neighbor). In this study, the image of banknotes as input data will go through the stages of preprocessing (cropping, grayscaling) and feature extraction (segmentation/thresholding) before entering the stage of detection of authenticity and nominal using FKNN. The final output is the result of detection of “real banknotes and nominal banknotes” or "fake banknotes”. The following is a description of the system built in this study:

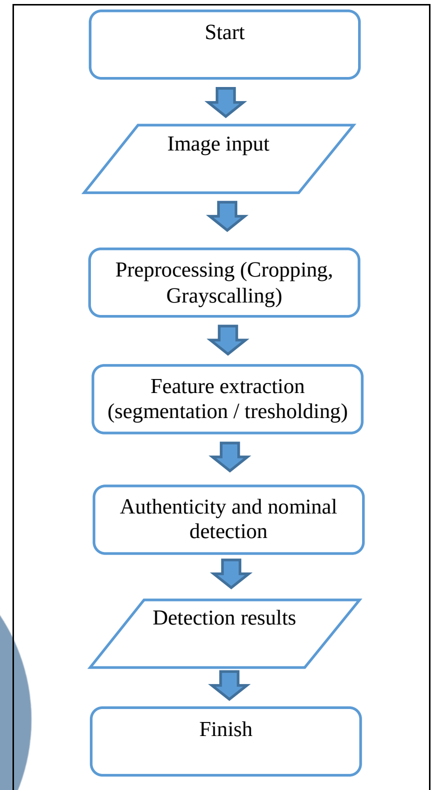


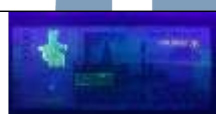
Figure 2. General description of the system

A. Citra Acquisition

In the study conducted by Putri (2015) [3] it was stated that in addition to the shape, color of the template, and the value of thresholding, the system of detection of the authenticity of banknotes was also greatly influenced by the distance/position of the camera to the position of the object. Therefore, in this study, the acquisition was carried out using a camera and detection box. The camera used is the Samsung A6 16 MP smartphone camera. The detection box (Figure 3) is a tool for acquiring banknotes images where the detection box is designed as a camera with a fixed distance between the camera and the banknotes to be acquired, which is 13 cm. The component in the detection box also has an ultraviolet light to bring in the invisible ink banknotes to be detected.

The banknotes dataset used is the back of IDR 100.000 and IDR 50.000, both for the old version (year 2004/2014 emissions) and the new version (2016 emissions) and fake banknotes made using inkjet print [13]. The following is the display of the dataset used in this study.

Table 1. Banknotes Datasets

No	Visual Banknotes	Results of Acquisition
1	Real banknotes (IDR 100.000, emissions in 2016)	
		
2	Real banknotes (IDR 50.000, emissions in 2016)	
		
3	Real banknotes (IDR 100.000, in emissions 2004/2014)	
		
4	Real banknotes (IDR 50.000, emissions in 2005)	
		
5	Fake Banknotes	
		

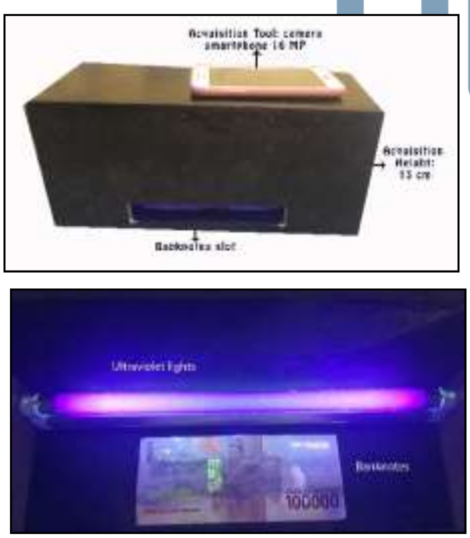


Figure 3. Banknotes Detection Box

Figure 4. Example of Image Acquisition Results

B. Cropping

At this stage, the image of the acquisitioned banknotes is cropped to 604 x 264 pixels, which is statically set on the system by determining the image pixel coordinates using the function in Matlab: *imcrop (capture, [10 133 603 263])*. Example of cropping results in Figure 5.

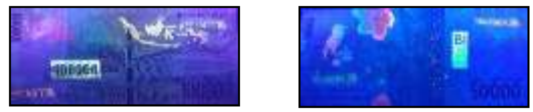


Figure 5. Cropping results

C. Grayscale

At this stage, the cropped image (RGB image) will then be converted into grayscale image using the rgb2gray function in Matlab. The following is an example of the conversion image to grayscale.

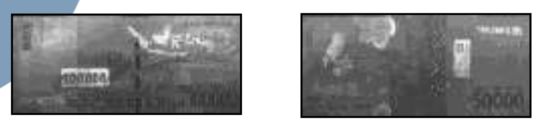


Figure 6. Example of Grayscale Results

D. Thresholding

Thresholding is a process used to produce binary images, namely images with only two colors, namely: black and white. Pixel values smaller or equal to 70 are initialized with pixel values = 0, while larger pixel values are initialized with pixel values = 1. So that the thresholding image is obtained as shown in Figure 7.

Figure 7. Example of Thresholding Results

E. Fuzzy K-Nearest Neighbor Classification

In this system, detection of authenticity and nominal image of banknotes inputted is done by classifying the results of thresholding features using FKNN. Based on the results of testing, obtained a minimum value of the degree of membership for the image of banknotes can be recognized correctly as real banknotes along with the nominal value of the banknotes that is U_i = 0.55. If the test image produces a membership degree value smaller than the minimum value of the membership degree (U_i = 0.55) then the test image is considered as counterfeit banknotes. The K parameter for FKNN used in this study is $K = 2$.

IV. Results and Discussion

In this system, the dataset is 24 images of banknotes, 5 images of the IDR 100,000 emissions in 2016, 5 images of the IDR 50,000 emissions in 2016, 5 images of the IDR 100.000 emissions in 2004/2014, 5 images of the IDR 50.000 emissions in 2005 and 4 images of fake banknotes. All images are acquired with a smartphone camera with a distance of 13 cm from the camera to the object and using the aid of a detection box (Figure 3). Furthermore, using a minimum value of membership degrees of U_i = 0.55 as the threshold for determining real banknotes and fake banknotes.

If the value of U_i => 0.55 and entered in class 1, it will be detected as IDR 100,000 emissions in 2016, if the value of U_i => 0.55 and enter in class 2, it will be detected as IDR 50,000 emissions in 2016, if the value of U_i => 0.55 and enter in class 3, it will be detected as IDR 100,000 emissions in 2014/2014, if the value of U_i => 0.55 and enter in class 4 it will be detected as IDR 50,000 emissions in 2005 and if U_i < 0.55 it will be detected as fake banknotes. The results obtained are shown in Table 2.

Table 2. Results of Banknotes Detection

Data testing		Membership Degree (Ui)	Detection Results	Evaluation
Real Banknotes IDR 100.000 emissions in 2016	Sample 1	0,6177	Real Banknotes	True
	Sample 2	0,6196	Real Banknotes	True
	Sample 3	0,6259	Real Banknotes	True
	Sample 4	0,6421	Real Banknotes	True
	Sample 5	0,6358	Real Banknotes	True
	Accuracy = 100%			
Real Banknotes IDR 50.000 emissions in 2016	Sample 1	0,6946	Real Banknotes	True
	Sample 2	0,5696	Real Banknotes	True
	Sample 3	0,6157	Real Banknotes	True
	Sample 4	0,6667	Real Banknotes	True
	Sample 5	0,7976	Real Banknotes	True
	Accuracy = 100%			
Real Banknotes IDR 100.000 emissions in 2004/ 2014	Sample 1	0,5639	Real Banknotes	True
	Sample 2	0,5741	Real Banknotes	True
	Sample 3	0,5992	Real Banknotes	True
	Sample 4	0,6235	Real Banknotes	True
	Sample 5	0,5102	Fake Banknotes	False
	Accuracy = 80%			
Real Banknotes IDR 50.000 emissions in 2005	Sample 1	0,5544	Real Banknotes	True
	Sample 2	0,6593	Real Banknotes	True
	Sample 3	0,5521	Real Banknotes	True
	Sample 4	0,6017	Real Banknotes	True
	Sample 5	0,6083	Real Banknotes	True
	Accuracy = 100%			
Fake Banknotes	Sample 1	0,5085	Fake Banknotes	True
	Sample 2	0,5041	Fake Banknotes	True
	Sample 3	0,5136	Fake Banknotes	True
	Sample 4	0,5017	Fake Banknotes	True
	Accuracy = 100%			
Total Accuracy = 96%				

Based on the data in Table 2, it can be seen that in the third experiment of the IDR 100.000 emissions in 2004/2014, an accuracy of 80% was obtained. Detection errors are caused by poor banknotes conditions so that invisible ink on banknotes is less visible and a lot of noise is read when classifying.

As for the first experiment of the IDR 100,000 emissions in 2016, the second experiment of the IDR 50,000 emissions in 2016, the fourth experiment of the IDR 50.000 emissions in 2005 and the fifth experiment of fake banknotes, the overall accuracy of 100%. Thus, overall from the five trials using 24 test data, obtained an average accuracy of 96%. This shows that the system built can detect the authenticity of rupiah banknotes.

Furthermore, from the results of the test, it was also found that the results of detection using the segmentation thresholding method were strongly influenced by variations in rotation and banknotes position during image acquisition. In addition, the detection results are also influenced by the condition and condition of banknotes that is still good or already worn out, because if the banknotes situation is not good then invisible ink that appears during the acqUisition will be difficult to detect on this system.

V. Conclusion

Based on the analysis of the results of the tests that have been carried out, it can be concluded that the system has been able to detect the authenticity of banknotes properly using a detection box aid at a distance of the camera with an object of 13 cm. Variations in rotation, position, and condition of banknotes at the time of image acquisition of banknotes greatly affect the detection of the authenticity of banknotes. In addition, the thresholding value used in the segmentation stage is also a factor that influences the accuracy of the results of detection of the authenticity of banknotes in this study.

The suggestion for the development of a banknotes authenticity detection system that takes the invisible ink characteristic of banknotes is to use a method that is not influenced by variations in rotation, position and distance at the time of image acquisition. In addition, it is strongly recommended to use a good camera and filter that can produce good quality images of banknotes.

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