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Counterfeit Currency Detection on Indonesian Banknotes Based on Latent Image Security Feature

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ABSTRACT

The advancement in printing technologies is in line to the advancement in money counterfeiting technologies, especially in Indonesian banknotes. The authorities are trying to protect the Indonesian banknotes from counterfeiting by embedding up to 12 security features on the banknotes.By its characteristic, the security features are divided into three, which are open, semi-open and closed. However, with so many security features, counterfeit currency on Indonesian banknotes still circulating because the counterfeiters can make a banknote that is very similiar to the original banknote. But, the counterfeiters pay less attention to the details of latent image security feature. Latent image is a semi-open security feature that must be viewed carefully to be able to recognize it.Although this feature can be printed and falsified, the quality of this feature on conterfeit banknotewas very bad. Based on this, original banknote and counterfeit banknote can be detected and classified according to the latent image security features.This research aims to develop a method for detecting the authenticity of banknotes using Deep Learning technology with the Convolutional Neural Network (CNN) architecture. Outcome of the research can be used to develop an expert system for counterfeit banknotesdetection on Indonesian currency.

Key words: Conterfeit Detection, Conterfeit Currency,Indonesian Banknotes, Latent Image, Convolutional Neural Network.

1. INTRODUCTION

Currency refers to money in any form when being used as a medium for exchange, especially circulating coin and banknote. Money is a modern payment instrument that is commonly used in one place to carry out the transaction for purchase and sale of goods or services [1].Bank Indonesia is the only one which has the full authority to issue the currency in Indonesia. However, there are some criminal fromcounterfeiting currency who printed the currency illegally by using the advancement in printing technologies.The counterfeit currency circulating at the same time as the original currency and not only causes harm to society but also harms the government because the circulation of counterfeit currency can cause an inflation at the country [2].

Detection of counterfeit currency needs to be done to find and separate the counterfeit currency from the currency circulationoverall. With the advancement of banking services, the detection method for counterfeit currency has become very important especially on Automated Teller Machine (ATM) that can accept cash deposit. In addition, the society also needs an automatic detection system to recognize the original currency and the counterfeit currency faster. Based on this consideration, this research will be carried out by utilizing the development of Deep Learning which will be used as an automatic detection method to classify the original currency and the counterfeit currency on Indonesian banknotes.

2. LITERATURE REVIEW

2.1 Security Feature on Indonesian Banknotes

On the IDR100,000 denomination in 2016 emissions, there are 12 security features in accordance with the official article published by Bank Indonesia Money Management Department [3] as:

1. Money Material;
2. Money Color;
3. Security Thread;
4. Colour Shifting Ink;
5. Multicolour Latent Image;
6. Special Printing Technique;
7. Blind Code;
8. Watermark;
9. Rectoverso;
10. Invisible Ink
11. Microtext;
12. Latent Image;

2.2 Latent Image on Indonesian Banknotes

Latent image is the result of printing technique that printing more than one object in one place that will appear clearly when viewed from a different points of view, angle or filters.Latent image on IDR100,000 of Indonesian banknotes is shown in Figure 1.

Figure 1: Latent Image on IDR100,000

2.3 Related Works

In general, research related to the topic of detecting counterfeit banknotes has been carried out, especially in India [4]. For Indonesian banknotes, there are a little number of research for detecting counterfeit banknotes. Based on the results ofseveral research that have been done, the most method for detecting counterfeit banknotesis Edge Detection using Canny Operator.

Y. Rijal in 2008 conduct a research for identification of authenticity currency on Indonesian banknotes [5], the research using IDR10,000 as the dataset; Fourier Transform using Neural Learning Vector Quantization as the method; Invisible Ink as the security feature. And the result of the research is recognize the invisible ink on banknotes.

In 2013, a research was conducted by M. Akbar using Edge Detection with Canny Operator [6]. Dataset that used in the research is fully scanned image of IDR100,000 2014 emission on Indonesian banknotes, the research is using watermark as the security feature. The result show a good segmentation but less of accuracy because if the counterfeit banknote has a watermark even in bad quality, the system detecting it as an original banknote.

A research was conducted in 2014 by E. D. Ginting using Edge Detection with Canny Operator [7]. Using watermark security feature and IDR100,000 as the dataset. In the research, scanned image that used as the dataset is only around watermark security feature. The result is the system able to recognize the watermark security feature on original banknotes, and if the system unable to recognize the watermark security feature on banknote, the banknote will classify as a counterfeit banknote.

The research by U. U. Rachman in 2017 is using Support Vector Machine on Android-based verification system [8]. The proposed technique is based on statistical features,and surface roughness of a banknote, representing different properties of the banknote, such aspaper material, printing ink, paper quality, and surface roughness. The research using Pakistan banknotes and the proposed method has been successfully got 92% of accuracy from the trained dataset.

In 2018, A. Kamble and Prof. M. S. Nimbarte conduct a research for detecting counterfeit banknote using Edge Detection with Sobel and Prewitt Operation [9]. The research using Indian banknote as the dataset with 35 image of original banknote and 15 image of counterfeit banknote. The result is the research produse a model for feature extraction on Indian banknote and successfull to classify the original banknote and the counterfeit banknote with 97% of accuracy.

R. Kitagawa in 2017 conduct a research on banknote detection using convolutional neural network [10], the result of this research is convolutional network able to recognize banknote and classifing it based on its denomination.

S. H. Lee and H. Y. Lee in 2018 proposed Deep Learning as a method for detecting currency counterfeit on Korean banknote [11]. The security feature used on this research is printing quality, the research using 36 original banknote that copied with 3 different printers that produce 10.800 image. The result of the research is deep learning able to used to classify the original banknote and the counterfeit banknote on Korean banknote.

The conclusion based on the existing research is deep learning can be used for detecting counterfeit currency, the most method that has been used is Edge Detection, India banknote is the most using as dataset on existing research, latent image is not commonly usedfor automatic detection of counterfeit currency, the dataset using on Edge Detection method is no more than 50 image.

3. RESEARCH METHODOLOGY

3.1 Denomination forDataset

Newest emission of Indonesian banknote is 2016 emission that has seven denominations: IDR1,000, IDR2,000, IDR5,000, IDR10,000, IDR20,000, IDR50,000, and IDR100.000. The most findings of counterfeit banknote are found on Rp.100.000,- denominations which are the biggest denomination on Indonesian banknotes. Based on this, the research will use dataset of IDR 100,000 2016 emission.

3.2 Dataset Gathering

This research using 17 original banknote and 17 counterfeit banknote. The original banknote is randomly came from Automated Teller Machine. The purposed of using 17

different original banknote is every banknote have any different slick level and different soil level. This will make many variations onoriginal dataset. The counterfeit banknote is came from Bank Indonesia counterfeit currency labroratory. The counterfeit banknote is also have a different counterfeiters, that mean the counterfeit banknote will have different characteristic on printing method. This will make many variations on counterfeit dataset.

After collecting 34 banknote (17 counterfeits and 17 originals), the banknote will be captured 10 times in 7 timelapse by one smartphone camera.In addition to get bigger dataset, this way also produce more variations of dataset because of different angle, different place, different lighting and different distance will produce more variations on dataset. Figure 2 will show the sample of captured original banknotes and Figure 3 will show the sample of captured counterfeit banknotes.

Figure 2: Captured Original Banknote

Figure 3: Captured Counterfeit Banknote

After capturing all of the banknotes, the dataset now having 1190 original banknote image and 1190 counterfeit image.

3.3 Image Pre-processing

This research will use the latent image security feature, therefore image pre-processing must be done. All of 2380 images will be crop using a batch cropping software and produce the latent image dataset. The location of cropping is around the location of latent image that shown in Figure 1.In effect by using batch cropping software, the image that produce by this way is got more variations. Figure 4 will show the sample of original latent image dataset and figure 5 will show the sample of counterfeit latent image dataset.

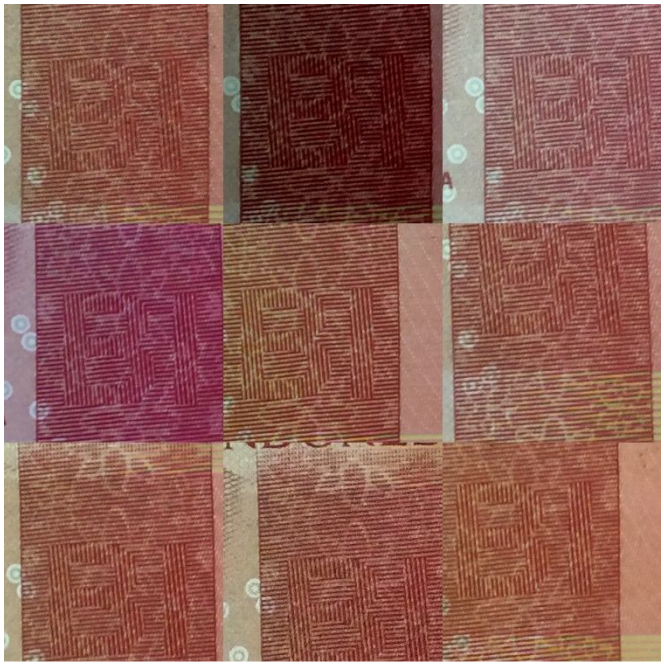

Figure 4: Original Latent ImageDataset

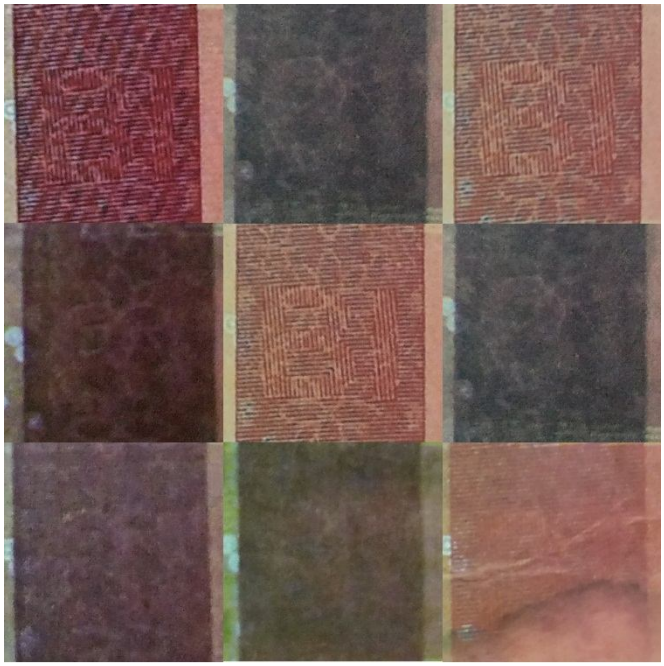

Figure 5: Counterfeit Latent Image Dataset

After cropping all images of banknote, the dataset now having 2380 latent images of banknote that consisting of 1190 original latent images on dataset and 1190 counterfeit latent images on dataset. This dataset will be used for training, validation and testing process using pretrained networks of deep learning with convolutional neural network.

3.4 Deep Learning Models

Within the dataset of this research, using scratch network is not recommended because of the little amount of total images data. Availability of the pretrained network should be the answer for this research. Therefore, this research will be use and comparison three of the pretrained network [12-15]: VGG-16 network that developed by Oxford Visual Geometry Group, GoogLeNet that developed by Google, and ResNet-50 that developed by Microsoft.The number of convolutional layers and Learnable parameters is shown in Table 1.

Table 1: Number of convolution layer and learnable parameters

Name of Pre-trained Network	Number of Convolution Layers	Number of Learnable Parameters
VGG-16	16	138M
ResNet-50	50	25.6M
GoogLeNet	22	7M

In this research, the original banknote will labeled as original 1-original 17 while the counterfeit banknote will labeled as counterfeit 1-counterfeit 17.The dataset will be split into three path. First path is dataset for training networks that containing images from both banknote datasetlabeled with number 1-10 which means the training dataset have 1400 images that consist 700 images of original banknotes and 700 images of counterfeit banknotes. The second path is dataset for validation on training network process that containing images from both banknote dataset labeled with number 11-14 which means the validation dataset have 560 images that consist 280 images of original banknotes and 280 images of counterfeit banknotes. The third path is dataset for testing networks that containing the rest of imageslabeled with number 15-17 which means the validation dataset have 420 images that consist 210 images of original banknotes and 210 images of counterfeit banknotes. Table 2 will show the distribution images to each dataset path.

Table 2: Dataset Path

Dataset Path	Image label	Dataset Original	Dataset Counterfeit	Total Image
Training	1-10	700	700	1400
Validation	11-14	280	280	560
Testing	15-17	210	210	420

3.5 Performance Measure

After training and validation network, the next step is testing the image on testing dataset to the pretrained network. The testing results will showan amountof data that was sucessfully classified, which the performance of the test results will be evaluated using a confusion matrix. Table 3 will show the parameters of confusion matrix in this research.

Table 3: Confusion Matrix Parameters

		Actual	
		Original	**Counterfeit**
Predicted	**Original**	TP	FP
	Counterfeit	FN	TN

True Positive (TP) is an image that labeled with Original Banknote that predicted as Original Banknote.
False Positive (FP)is an image that labeled with Counterfeit Banknote that predicted as Original Banknote.
False Negative (FN)is an image that labeled with Original Banknote that predicted as Counterfeit Banknote.
True Negative (TN)is an image that labeled with Counterfeit Banknote that predicted as Counterfeit Banknote.

From the comparison of the parameters, can be obtained the sensitivity, specificity and accuracy of the networks based on mathematical equation as follow:

$$\text{Sensitivity} = \frac{TP}{TP+FN}$$

$$\text{Specificity} = \frac{TN}{TN+FP}$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN}$$

4. IMPLEMENTATION

The Implementation process starting by building a pretrained network using deep learning toolbox on MatLab and then installing VGG-16 Toolbox, ResNet-50 Toolbox and GoogLeNet Toolbox. After that, the training and validation progress to the dataset using pretrained network started from VGG-16, ResNet-50 and the last is GoogLeNet. Figure 6 will show the training and validation result of VGG-16. Figure 6 will show the training and validation result of ResNet-50. And Figure 6 will show the training and validation result ofGoogleNet.

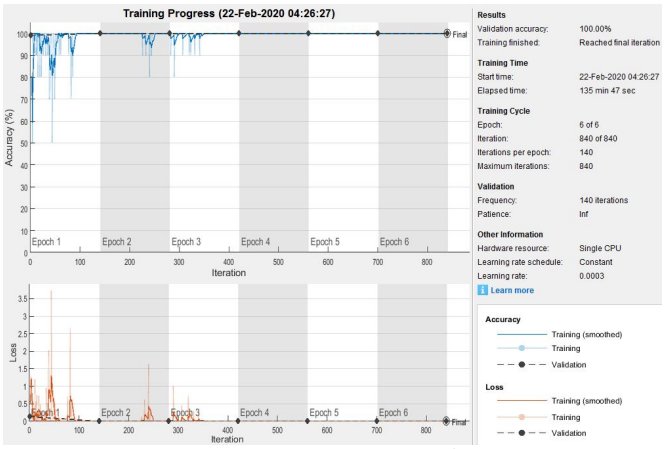

Figure 6: Training and Validation Result of VGG-16 network

Figure 7: Training and Validation Result of ResNet-50 network

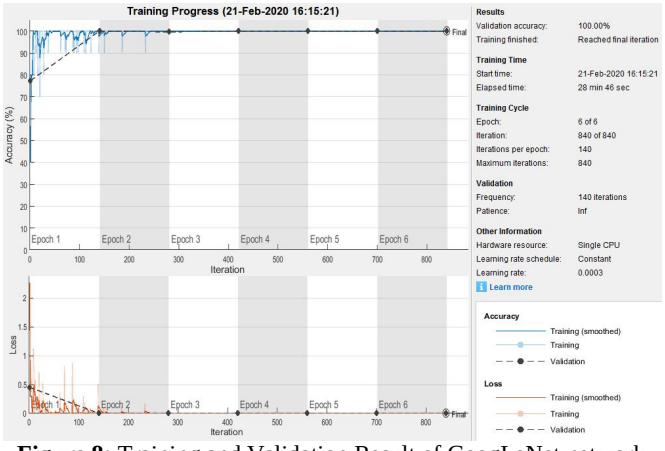

Figure 8: Training and Validation Result of GoogLeNet network

Based on Figure 6, 7, 8, the result of training and validation dataset using pretrained network show the same accuracy. The accuracy of dataset training and validation is 100% in all pretrained network (VGG-16, ResNet-50 and GoogLeNet) but the training time show the different result. Based on training time, GoogLeNet is the fastest network with elapsed time 28 mins and 46 sec. After that, there is ResNet-50 with elapsed time 84 mins and 38 sec. The last one is VGG-16 with elapsed time 135 mins and 47 sec. Table 4 is show the result of validation result on trainednetwork using original and counterfeit banknotes of indonesian currency.

Table 4: Result of Validation Process on Trained Network

No	Network	Accuracy	Training Time
1	VGG-16	100%	135 mins and 47 sec
2	ResNet-50	100%	84 mins and 38 sec
3	GoogLeNet	100%	28 mins and 46 sec

After training and validation process, the next step is testing all networks using dataset testing that have been prepared based on table 2. Figure 9 is show the result of testing dataset using VGG-16 networks.Figure 10 is show the result of testing dataset using ResNet-50 networks.Figure 11 is show the result of testing dataset using GoogleNet networks.

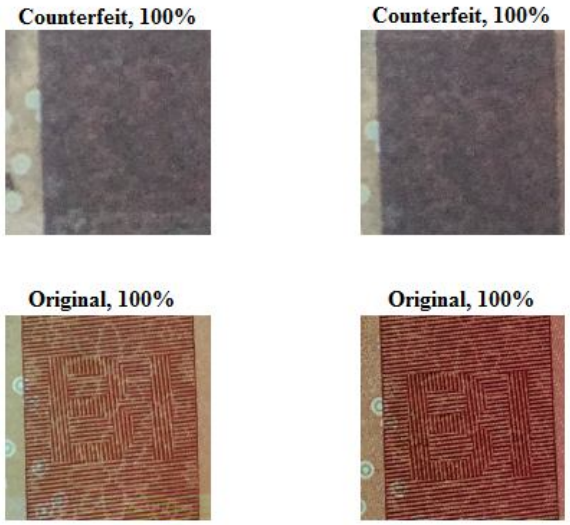

Figure 9: Testing Result of VGG-16 network

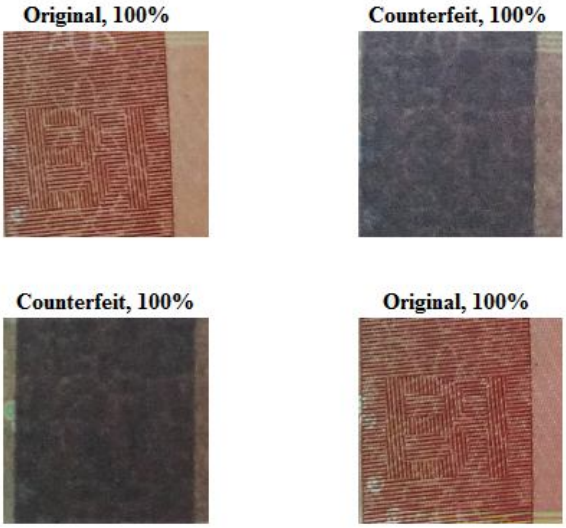

Figure 10: Testing Result of ResNet-50 network

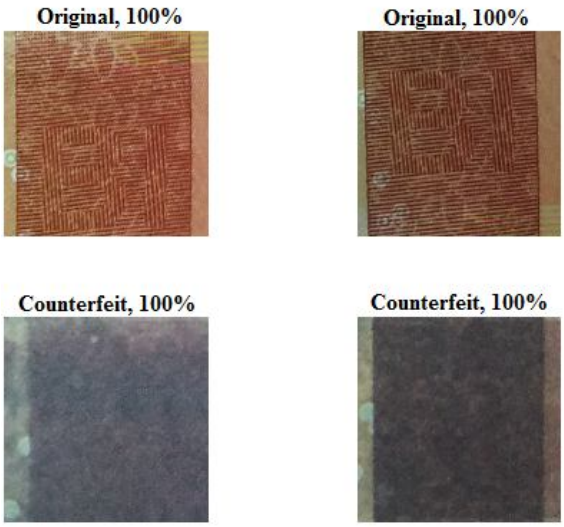

Figure 11: Testing Result of GoogLeNet network

5. EVALUATION RESULTS

The next step is evaluation of each pretrained network result as show in Table 3. Table 5 will show the confusion matrix for VGG-16 network.Table 6 will show the confusion matrix for ResNet-50 network.Table 7 will show the confusion matrix for GoogLeNet network.

Table 5: Confusion Matrix of VGG-16 Networks

		Actual	
		Original	**Counterfeit**
Predicted	**Original**	210	0
	Counterfeit	0	210

$$\text{Sensitivity} = \frac{TP}{TP+FN} = \frac{210}{210+0} = \frac{210}{210} = 1$$

$$\text{Specificity} = \frac{TN}{TN+FP} = \frac{210}{210+0} = \frac{210}{210} = 1$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} = \frac{210+210}{210+210+0+0} = \frac{420}{420} = 1$$

Table 6: Confusion Matrix of ResNet-50 Networks

		Actual	
		Original	**Counterfeit**
Predicted	**Original**	210	0
	Counterfeit	0	210

$$\text{Sensitivity} = \frac{TP}{TP+FN} = \frac{210}{210+0} = \frac{210}{210} = 1$$

$$\text{Specificity} = \frac{TN}{TN+FP} = \frac{210}{210+0} = \frac{210}{210} = 1$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} = \frac{210+210}{210+210+0+0} = \frac{420}{420} = 1$$

Table 7: Confusion Matrix of GoogLeNet Networks

		Actual	
		Original	**Counterfeit**
Predicted	**Original**	210	0
	Counterfeit	0	210

$$\text{Sensitivity} = \frac{TP}{TP+FN} = \frac{210}{210+0} = \frac{210}{210} = 1$$

$$\text{Specificity} = \frac{TN}{TN+FP} = \frac{210}{210+0} = \frac{210}{210} = 1$$

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} = \frac{210+210}{210+210+0+0} = \frac{420}{420} = 1$$

The result of this research are all of the pretrained network sucessfully classify the original and the counterfeit banknotes. This means that convolutional neural network can be used as detection method for counterfeit currency on Indonesian banknotes. The result also show that GoogLeNet is the best practice of pretrained network in this research because GoogLeNet get 100% accuracy and only takes 28 mins and 46 sec on training and validation process.

6. CONCLUSION

Circulation of the counterfeit banknotes must be reduced as mush as possible to avoid the inflation. The authorities may have provided many security features, but the prevention from end users is better for reducing the circulation of counterfeit money. This research is supporting a development of an expert system using deep learning with convolutional neural network architecture that can be used by society so the common people can detecting the counterfeit banknotes more faster and easily.

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