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A Counterfeit Paper Currency Recognition System Using LVQ based on UV Light

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Abstract*— This research is aimed to test a paper currency counterfeit detection system based on Linear Vector Quantization (LVQ) Neural Network. The input image of the system is the dancer object image of paper currency Rp. 50.000,- fluorescent by ultraviolet light. The image of paper currency data was taken from conventional banks. The LVQ method is used to recognize whether the paper currency being tested is counterfeit or not. The coding was carried out using visual programming language. The feature size of the dancer tested object is 114x90 px and the RGBHSI was extracted as the input for LVQ. The experimental results show that the system has an accuracy 100% of detecting 20 real test case data, and 96% of detecting 22 simulated test case data. The simulated case data was generated by varying the brightness of the image data. The real test case data contains of 10 counterfeit paper currency and 10 original paper currency. The simulated case data contains of 11 original paper currency and 11 counterfeit paper currency. The best setting for the system is Learning Rate = 0.01 and MaxEpoh = 10.

Keywords-CRM 2.0; detection system, counterfeit paper currency, neural network, LVQ, digital image processing

I. INTRODUCTION

That the RGB values from fluorescence invisible ink image by UV light, can be used as input for LVQ neural network to detect counterfeit paper currency has been proven with 100% accuracy [1]. In this paper, the accuracy of the system using RGBHSI as the input will be revealed.

On preliminary experiment, a detection system has been built based on Linier Vector Quantization (LVQ) neural network using UV's lamp to show up the original feature of original paper currency. It has been proved that this technique has 100% accuracy using cropping 90x114 pixels feature [2]. On the next experiment the cropping 114x90 pixels feature was used [1], which means, only part of original feature was used.

In this paper, the feature was taken from an image appear under an UV lamp. The LVQ will then recognize the pattern, thus it can be defined whether it is the original paper currency or the counterfeit.

II. THEORY

A. Neural Network (LVQ)

Neural network is adopted from biologic neural network of human and can be trained to recognize an object with specific pattern[3]. LVQ is one of supervised training methods to its competitive layers [4, 5, 6, 7, 8, 9]. A competitive layer automatically learn to classify input vectors. The classification result of competitive layer only depend on the distance between input vectors and weight vectors [10]. If there are two vectors where the distance is almost the same and nearest than the other, therefore, competitive layers will classify both of them into the same class.

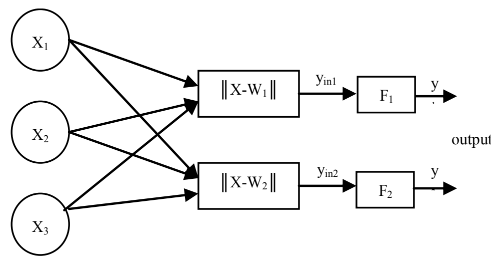

Figure 1. The LVQ Architecture

LVQ's network has two layers such as competitive and linear layers (Fig. 1). Neurons on competitive layers compete each other and produce the winning neuron [8]. The competitive layer classify input vector into the amount of clusters based on distances in each input vectors. On the second layer, linear layer mapped the clusters classified by the competitive layer into classes which has been defined by the user [11].

B. Digital Image Processing

A visual system has the ability to fix useful information from an image and use it for many things. The information will be used after several times of image processing [12].

Three basic quantities are used to describe the quality of a chromatic light source are: radiance, luminance, and brightness. Radiance is the total amount of energy that flows from the light source and is measured in watts (W). Luminance, measured in lumens (lm), gives a measure of the total amount energy an observer perceives from a light source. Brightness is a

Based on our works presented on ICID2011 [1]
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subjective descriptor that is practically impossible to measure [13].

Owing to the structure of the human eye, all colors are seen as variable combinations of the three so-called primary colors red (R), green (G), and blue (B). For the purpose of standardization, the CIE (*Commission Internationale de l'Eclairage-the International Commission on Illumination*) designated in 1931 the following specific wavelength values to the three primary colors: blue=435.8 nm, green=546.1 nm, and red= 700 nm [13].

Generally, the characteristic used to distinguish one color to another are brightness, hue, and saturation [13]. Brightness embodies the chromatic notion of intensity. Hue is associated with the dominant wavelength in a mixture of light waves, thus it represents dominant color as perceived by an observer, e.g. red, orange or yellow according to observer actually each of those are specification of a hue. Saturation is relative purity or the amount of white light mixed with a hue.

The HSI space is obtained by non-linear transformation of the RGB space. The HSI representation uses the brightness (or intensity) value, I (intensity) as the main axis orthogonal to the chrominance plane. The saturation S and the hue H are the radius and the angle, respectively, of the polar coordinates in the chrominance plane with the origin in the trace of the value axis (with R corresponding to 0^o) (Fig. 2):

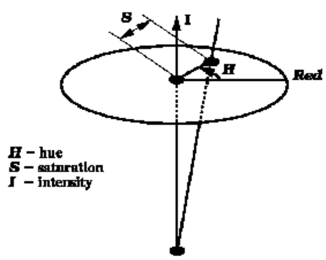

Figure 2. The HSI representation

This representation is approximately perceptually uniform and is closely related to the way the human vision perceives color images. Because of invariance to the object orientation with respect to illumination and camera viewing direction, the hue is more suitable for object retrieval. But the conversion from the RGB to HSI color coordinates is a bit complicated. Colors in HSI model are defined with respect to normalized red, green, and blue values:

$$r = \frac{R}{(R+G+B)}, \qquad [0,1] \tag{1}$$

$$g = \frac{G}{(R+G+B)}, \qquad [0,1] \tag{2}$$

$$b = \frac{B}{(R+G+B)}, \qquad [0,1] \tag{3}$$

For any three R, G, and B color components, each in the range [0,1], the intensity component in the HSI model is defined as

$$I = \frac{1}{3\times 255}(R+G+B), \qquad [0,1] \tag{4}$$

$$S = 1 - 3\min(r,b,g), \qquad [0,1] \tag{5}$$

$$H = \begin{cases} \delta & \text{if } b < g, \quad [0,\pi] \\ 2\pi - \delta & \text{otherwise}, \quad [\pi, 2\pi] \end{cases} \tag{6}$$

$$\delta = \cos^{-1}\left\{ \frac{\frac{1}{2}[(r-g)+(r-b)]}{[(r-g)^2 + (r-b)(g-b)]^{1/2}} \right\} \tag{7}$$

where $b = \min(r,b,g)$ in the RG sector.

For convenience, H, S and I values are converted in the ranges of [0,360], [0,100], [0, 255] respectively by:

$$H = H \times 180/\pi; \qquad S = S \times 100; \qquad I = I \times 255 \tag{8}$$

C. Ultraviolet

UV is an electromagnetic radiation with shorter wavelength than visible light but longer than X-ray. Therefore, the energy of UV is bigger than visible light as in (9).

$$E = h\upsilon = \frac{hc}{\lambda} \tag{9}$$

where energy (E), h is Plank constant (6,626 x 10^{-34}Js), frequency (υ), light velocity (c) = 3 x 10^8 m/s, and wavelength (λ).

Moreover, UV has a lot of functions, e.g. to produce D vitamin and to detect counterfeiting of paper currency and credit card [14]. Invisible Ink and safety line in paper currency are used as security from counterfeiting and it is usually fluorescenced by UV [15].

III. METHODS

Methods of the research (Fig. 3):

A. Data Acquisition

Data acquisition process is needed to take a picture of the paper currency using these tools and setting:

1) Digital Camera ; setting ISO 800; Focus 3.1; Speed 1/15; no blitz, camera to object distance 21 cm.

2) LuxMeter Digital LX-100 Merk Lutron, Setting Scale: 0-1999 x 1 Lux

3) UV Lamp 10 Watt Sin Sen brands.

4) White lamp T5 8 Watt Sin Sen brands.

5) Power Regulator 220V

B. Preprocessing

It was done to extract the image feature from its background in order to make the next process easier. The image was cropped into the size of the paper currency and normalized to be 550x240px.

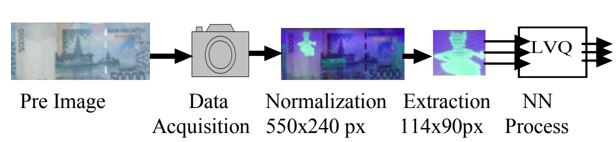

Figure 3. The detection system process

C. Feature Extraction

It is undergone to take the value of RGB and HSI from the feature so that LVQ can use it as the input and to classify the paper currency. The feature was taken from fluorescent image with size of 114x90 pixels then the RGBHSI values are extracted as input for LVQ.

First of all, the values of RGB were extracted then normalized as in (1) to (3), the RGB values were then converted into HSI as in (4) to (8). Finally, both RGBHSI were used as input for LVQ neural network.

D. Paper currency Detection

Detection by LVQ is based on the closest distance between test vector (testing image) with reference (weight) vector (training).

If classification is appropriate with the class target then use formula (10):

$$w_j(new)=w_j(last)+\alpha(x-w_j(last)) \tag{10}$$

If classification is inappropriate with the class target then use formula (11):

$$w_j(new)=w_j(last)-\alpha(x-w_j(last)) \tag{11}$$

Classification based on closest distance use formula (12):

$$\|X-W_2\|<\|X-W_1\| \text{ or } \|X-W_2\|>\|X-W_1\|, \tag{12}$$

where $\|X_i-W_{ij}\|= \sqrt{(x_1-w_{11})^2+(x_2-w_{21})^2+(x_3-w_{31})^2}$, i notation shows the total amount of input variables (six variables), and j shows the total amount of class target (two classes) [1, 2].

The system will do some tests i.e. Validation, Accuracy test with variation of Learning rate and Epoch, and tried to find the best setting to be applied.

IV. RESULT

A. Validation System

Validation is conducted by detecting the training images one by one so that the quality of system can be known. The testing images consist of seven counterfeit paper currencies and five original paper currencies. The neural network setting are MaxEpoh = 1000 and Learning Rate = 0.01. The result is shown in Table I.

TABLE I. VALIDATION RESULT

No	Files name (bmp)	Distance class 1	Distance class 2	Categories	Accuracy
1	50rb data asli2	262.8874	314.7337	1	True
2	50rb data palsu-2	317.2408	263.9249	2	True
3	asli utuh1	149.3534	194.5605	1	True
4	asli utuh2	169.7315	204.0747	1	True
5	asli utuh3	191.2581	215.1399	1	True
6	asli utuh4	210.0506	227.4419	1	True
7	palsu utuh1	202.8637	141.2639	2	True
8	palsu utuh3	245.7379	215.5518	2	True
9	palsu utuh4	267.9559	250.7049	2	True
10	palsu utuh5	293.5544	286.9850	2	True
11	palsu utuh6	311.5625	310.8619	2	True
12	palsu utuh7	314.0018	314.0018	1	False

Categories: 1 = original ; 2 = counterfeit

Each file has its own brightness level, they are respectively : 0% for data number 1 and 2, then 5%, 10%, 15%, 20% for the original paper currency, and 15%, 30%, 45%, 60%, 75%, 100% for counterfeit paper currency. The validation result is 91.7% worst than RGB input 100% correct in recognizing [1].

B. Testing

The system is tested using two types of data. First, the brightness level of data were variated from 0-100% using image external software. The image was taken from *Rupiah* currency with nominal 50.000 rupiahs. The system can detect to 96% accuracy. It was falsely detect one datum on counterfeit paper currency with 100% brightness level (Table II), similar with RGB input [1].

TABLE II. THE TESTING RESULT OF BRIGHTNESS VARIATION

No	Paper currency	Brightness (%)	Distance Class 1	Distance Class 2	Category class	Accuracy
1	Counterfeit	0	115.7959	104.4094	2	True
2		10	141.0405	117.1203	2	True
3		20	167.7492	138.7057	2	True
4		30	193.7533	164.3785	2	True
5		40	218.9924	191.4053	2	True
6		50	243.0435	219.3798	2	True
7		60	262.2889	243.9148	2	True
8		70	280.7306	269.2852	2	True
9		80	297.4170	292.1887	2	True
10		90	311.6113	310.8990	2	True
11		100	314.0018	314.0018	1	False
12	Original	0	98.0862	173.9293	1	True
13		10	141.1118	185.2413	1	True
14		20	180.2797	205.7115	1	True
15		30	212.9119	229.9079	1	True
16		40	242.5061	255.1035	1	True
17		50	269.3904	278.9219	1	True
18		60	292.1109	298.9612	1	True
19		70	309.2809	312.2573	1	True
20		80	313.9621	313.9716	1	True
21		90	314.0018	314.0018	1	True
22		100	314.0018	314.0018	1	True

Categories: 1 = original ; 2 = counterfeit

The image where the brightness level is 100% has no histogram (like white paper), therefore the LVQ found the same vector distance. Thus, it was classified as class 1 (original) which has been programmed for anticipation.

Second, the test used the data which has been variated using external light consist of 10 counterfeit paper currency and 10 original paper currency images. The test result of original paper currency (lux): 28, 40, 51, 60, 70, 80, 91, 101, 110, 111, and for counterfeit paper currency (lux): 19, 40, 60, 81, 100, 120, 140, 160, 180, 200 respectively, which is 100% correct (Table III). Compared with RGB input, the result is the same [1].

TABLE III. THE TEST RESULT OF INTENSITY VARIATION

No	Paper currency	Intensity (…± 1) Lux	Distance Class 1	Distance Class 2	Categories	Accuracy
1	Original	28	33.0533	179.5724	1	True
2		40	75.4598	158.1359	1	True
3		51	72.2703	156.1656	1	True

4		60	125.4697	177.2176	1	True
5		70	153.5062	188.6315	1	True
6		80	146.2801	186.5987	1	True
7		91	145.2419	187.5221	1	True
8		101	158.3346	204.3322	1	True
9		110	184.3026	213.8314	1	True
10		111	149.4854	194.7754	1	True
11	Counterfeit	19	209.6480	201.2839	2	True
12		40	221.6989	214.8142	2	True
13		60	231.0037	224.1013	2	True
14		81	231.9535	223.5377	2	True
15		100	224.4563	214.6607	2	True
16		120	233.7855	225.7243	2	True
17		140	236.1947	228.1009	2	True
18		160	238.1816	229.5155	2	True
19		180	236.7855	229.1903	2	True
20		200	238.1862	230.3989	2	True

Categories: 1 = original ; 2 = counterfeit

C. *The effect of learning rate*

In order to observe the learning rate of LVQ, the system is tested using 22 brightness variation data. The result is shown in Table IV.

TABLE IV. LEARNING RATE'S EFFECT WITH MAXEPOH=1000

No	Paper currency	Brightness (%)	Category class				
			LR= 0.001	*LR= 0.01*	*LR= 0.02*	*LR= 0.03*	*LR= 0.04*
1		0	2	2	2	2	2
2		10	2	2	2	2	2
3		20	2	2	2	2	2
4		30	2	2	2	2	2
5		40	2	2	2	2	2
6	Counterfeit	50	2	2	2	2	2
7		60	2	2	2	2	2
8		70	2	2	2	2	2
9		80	2	2	2	2	2
10		90	2	2	2	2	2
11		100	1	1	2	1	2
12		0	1	1	1	1	1
13		10	1	1	1	1	1
14		20	1	1	1	1	1
15		30	1	1	1	1	1
16		40	1	1	1	1	1
17	Original	50	1	1	1	1	1
18		60	1	1	1	1	1
19		70	1	1	1	1	1
20		80	1	1	1	1	1
21		90	1	1	2	1	2
22		100	1	1	2	1	2

Categories: 1 = original ; 2 = counterfeit

It is shown that the best Learning Rate is 0.02 based on speed of system learning and accuracy. Smaller learning rate for LVQ neural network does not guarantee that it will have the best result. But if it will be applied to a machine, the best result is Learning Rate 0.04 because it was faster and for brightness more than 70% (almost white) will not be found in reality (Fig. 4).

Figure 4. The original paper currency with 70% brightness

The best Learning rate for RGBHSI input is different with RGB input which was 0.01 [1]. It shows that every input system has their own characteristic.

D. *The effect iteration (Epoch)*

Table V shows that varying epoch gives different result and does not guarantee that bigger epoch will has the best result. The best result for the system is MaxEpoch 1. Logically, smallest epoch makes the system run faster in learning but often has more detection errors.

TABLE V. MAXEPOCH VARIATION WITH LEARNING RATE =0.01

No	Paper currency	Brightness (%)	Category class				
			ME= 10000	*ME= 1000*	*ME= 100*	*ME= 10*	*ME= 1*
1		0	2	2	2	2	2
2		10	2	2	2	2	2
3		20	2	2	2	2	2
4		30	2	2	2	2	2
5		40	2	2	2	2	2
6	Counterfeit	50	2	2	2	2	2
7		60	2	2	2	2	2
8		70	2	2	2	2	2
9		80	2	2	2	2	2
10		90	2	2	2	2	2
11		100	1	1	2	2	1
12		0	1	1	1	1	1
13		10	1	1	1	1	1
14		20	1	1	1	1	1
15		30	1	1	1	1	1
16		40	1	1	1	1	1
17	Original	50	1	1	1	1	1
18		60	1	1	1	1	1
19		70	1	1	1	2	1
20		80	1	1	1	2	1
21		90	1	1	2	2	1
22		100	1	1	2	2	1

Categories: 1 = original ; 2 = counterfeit

In order to get the best setting for the best result an appropriate tool is needed, the system is tested with different setting (Table VI). It reveals that the best result is MaxEpoch=10 and Learning rate=0.01. Using that setting, the system can detect good enough for brightness variation for all counterfeit paper currency and original paper currency until 60% in variation. Moreover, with this setting the system can detect with 100% accuracy for real data with intensity variation.

TABLE VI. THE BEST SETTING

No	*Paper currency*	Intensity (…± 1) Lux	Category class					
			ME= 1000 LR= 0,01	*ME= 1000 LR= 0,02*	*ME= 1000 LR= 0,04*	*ME= 1 LR= 0,01*	*ME= 10 LR= 0,01*	*ME= 100 LR= 0,01*
1		28	1	1	1	1	1	1
2		40	1	1	1	1	1	1
3		51	1	1	1	1	1	1
4		60	1	1	1	1	1	1
5	Original	70	1	1	1	1	1	1
6		80	1	1	1	1	1	1
7		91	1	1	1	1	1	1
8		101	1	1	1	1	1	1
9		110	1	1	1	1	1	1
10		111	1	1	1	1	1	1
11	Cou	19	2	2	2	2	2	2

12	nterf	40	2	2	2	2	2	2
13	eit	60	2	2	2	2	2	2
14		81	2	2	2	2	2	2
15		100	2	2	2	2	2	2
16		120	2	2	2	2	2	2
17		140	2	2	2	2	2	2
18		160	2	2	2	2	2	2
19		180	2	2	2	2	2	2
20		200	2	2	2	2	2	2

Categories: 1 = original ; 2 = counterfeit

V. CONCLUSION

It is revealed that UV lamp can be used to shows up the invisible ink in original paper currency and use it as the unique feature for LVQ neural network to distinguish between original and counterfeit paper currency. In addition, the most appropriate setting to get the best accuracy for a machine implemention is Learning Rate = 0.01 and MaxEpoh = 10. The accuracy of RGBHSI are 100% for real data and 96% for simulated data. Finally, for next research is aimed to make the system usable for more general paper currency data based on the invisible ink.

REFERENCES

[1] Harjunowibowo, D. and Hartati, S., 2011, “LVQ Neural Network based on Ultraviolet for Money Counterfeiting Detection”, Proceeding, ICID2011, Yogyakarta.

[2] Harjunowibowo, D., 2010, “Perangkat Lunak Deteksi Uang Palsu Berbasis LVQ Memanfaatkan Ultraviolet”, Proceeding, Surakarta.

[3] Haykin, S, 1998, “Neural Networks”, Macmillan College Publishing Company, NY USA.

[4] Fu, L. M, 1994, “Neural Network in Computer Intelligence”, Internasional Edition, Mc Graw Hill Co., Singapore.

[5] Fausett, L., 1994. “Fundamentals of Neural Networks:Architectures, Algorithms, and Applications”, Prentice-Hall, New Jersey.

[6] Azis, A., Sunarminto, B.H. dan Renanti, M. D., 2006, “Evaluasi Kesesuaian Lahan Untuk Budidaya Tanaman Pangan Menggunakan Jaringan Syaraf Tiruan”, Berkala MIPA Journal, 16(1), Januari.

[7] Ranadhi, D., Indarto, W. dan Hidayat, T., 2006, **“**Implementasi Learning Vektor Quantization (LVQ) untuk Pengenal Pola Sidik Jari pada Sistem Informasi Narapidana LP Wirogunan”, Media Informatika Journal, Vol 4, No 1, Yogyakarta.

[8] May, IL, Sumardi, dan Hidayatno, A., 2002, “Pengenalan Vokal Bahasa Indonesia Dengan Jaringan Syaraf Tiruan Melalui Transformasi Wavelet Diskret”, Simposium Nasional I RAPI 2002.

[9] Umer, M.F., and Khiyal, M.S.H., 2007, “Classification of Textual Documents Using Learning Vektor Quantization”, Information Technology Journal 6 (1): 154-159

[10] Irawan dan Satriyanto, 2008, “Virtual Pointer Untuk Identifikasi Isyarat Tangan Sebagai Pengendali Gerakan Robot Secara Real-Time”, Jurnal Informatika, Vol. 9, No.1, Mei, pp. 78-85

[11] Annisa dan Widyanto, M.R., 2007, “Perbandingan Kinerja Jaringan Syaraf Tiruan dan Algoritma Klasifikasi ARM”, Proceedings of National Conference on Computer Science & Information Technology 2007, January 29-30, Fakultas Ilmu Komputer Universitas Indonesia.

[12] Ahmad, U., 2005, “Pengolahan Citra Digital dan Teknik Pemrogramannya”, edisi 1, Penerbit Graha Ilmu, Yogyakarta

[13] Gonzalez, R.C., dan Woods, R.E., 1993, “Digital Image Processing”, Penerbit Addison-Wesley Inc., ed. September, USA.

[14] Grant, W. B., 2002. “An Estimate of Premature Cancer Mortality in The U.S. Due to Inadequate Doses of Solar Ultraviolet-B Radiation”. Cancer, Volume 94, hal. 1867-1875.

[15] Anonim, 2003, “Hindari Uang Palsu, Optimalisasi Fasilitas Perbankan”, 2003, http://www.sinarharapan.co.id/uang&efek/gaya%20hidup/2004/0407/gaya01.html, accessed on 24th of Juni 2006.

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