ASEAN+3 Banknote Recognition System (A+3BRS)

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Abstract

Nowadays, the banknote is the most frequently used currency in the economy even though there is technology for internet banking that can trade and exchange things easier. ASEAN+3 Banknote Recognition System (A+3BRS) is an image recognition application, which is used for recognizing and converting exchange rates for each unique banknote in ASEAN+3 countries. The A+3BRS database stored the data of 6,500 banknotes from 108 current different currencies include the exchange rate. The system was applied artificial neural network for classifying paper currency. The A+3BRS is developed and tested on 598 random images and the test results are classified into mobile-phone captured pictures, internet banknote pictures, outside ASEAN+3 banknotes, and kids toy banknotes. The accuracy rate of the experimental results are 53.50, 73.75, 100.00 and, 100.00 per cent respectively. The A+3BRS average access time are 0.8593 seconds per image.

Keyword: ASEAN+3, Banknotes, Exchange Rate, Pattern Recognition, Image Processing, Intelligent System.

I. Introduction

ASEAN (The Association of Southeast Asian Nations) consists of ten countries, which are Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The ASEAN+3 includes the 10 members of the ASEAN plus the China, Japan, and Korea.

Before coins and banknotes were created, people used many mediums of exchange to exchange things. Sometimes it was unfair and imbalanced to exchange things e.g. trading chickens for a pig, or a house for a car. The first time the coins were introduced, coins made the trading system easier, but coins can be counterfeit and are it is difficult to keep sufficient coins in one's pockets. Afterwards, banknotes were introduced into the trading system, and banknotes are currently mainly used in most trading systems even though banknotes can be easier to counterfeit than a coin. Over the centuries, currency has been the initiative to negotiate or exchange for things, for example foods, products, properties, utilities, etc. Currency mainly known as coins and banknotes, are used in every economy system to process the business.

Nowadays, economy systems mainly use coins, banknotes and gold to run the business. The currencies are uniquely created to make the money usable in a specific area. Even though now people have many methods of trading such as electronic money or stocks trading, people still use the physical currency because banknotes and coins are the most secure and touchable things. Sometimes, the physical currency can create confusion and difficulty to foreign traders who want to know what is the difference between a current country's money and a trader's currency. The sample of ASEAN+3 banknotes are shown in Figure 1. This is the most troublesome challenge in the economy system when trading money with others.

The objective of this project is to develop a computer system, which can identify the types of banknotes. This can help people from struggling and confusing the kind of banknote. This system can help people who use it for knowing what the exchange rate for each country is and checking the country of origin of the banknote.

Figure 1

The ASEAN+3 banknotes sample, which are: (a) Brunei, (b) Cambodia, (c) Indonesia, (d) Laos, (e) Malaysia, (f) Myanmar, (g) Philippines, (h) Singapore, (i) Thailand, (j) Vietnam, (k) China, (l) Japan and (n) South Korea

II. Literature Reviews

Many scientists and researchers developed a variety banknotes recognition system. The purposes of the system are recognizing banknotes in automatic teller machine (ATM), vender machine and detecting counterfeit banknotes in the treading system etc. They apply many techniques to conduct their experiments. The brief details of each research technique are as follow.

A. Hidden Markov Model (HMM)

The Hidden Markov Model is a ubiquitous tool for modeling time series data. They are used in pattern recognition applications. Shan, (2009) designed the HMM-based banknote recognition system. The system database used more than 16,000 Chinese Yuan Renminbi (CNY or RMB) banknotes to train the system. The precision rate of the system are 93.20 per cent. Hassanpour, (2009) using HMM for paper currency recognition. The developed system employed banknote histogram to recognize US dollar banknotes with the precision rate of 98.00 per cent.

B. Rule-based system

Each banknote has its set of conditions, such as colors, size and texture. Researchers apply many rules to identify each banknotes. Sevkli, (2019) applied inductive learning to recognize Turkey banknotes. This system also applied Sobel edge detection to recognize the banknote. Abburu, (2017) employed size, color and text features to recognize twenty countries currency.

C. Euclidean distance

The Euclidean distance is a value between two objects, such as the different value between an unknown banknote and a training banknote color. Shoeb, (2016) used GLCM (gray-level co-occurrence matrix) texture features, which are contrast, correlation, energy and homogeneity with the Euclidean distance technique to identify the Egyptian currency counterfeiting. Akter, (2018) developed the Bangladeshi paper-currency recognition system by using Euclidean distance method.

D. Support vector machines (SVM)

The SVM is an effective tool for solving classification problems. Yeh, (2011) using SVM to identify Taiwan paper-currency counterfeit. The accuracy of the system are 93.55 per cent. Tessfaw, (2018) recognized Ethiopian banknotes counterfeit by SVM technique. The precision of the system are 98.00 per cent. Dittimi, (2017) conducted the US dollar, Canadian dollar and Euro banknotes by using SVM-based with the precision rate of 99.00 per cent.

E. Artificial neural networks (ANN)

The ANN is a computer technique to simulate human nervous system for solving complex problems. Lamont, (2012) applied color and texture features with a linear vector quantization (LVQ) network to recognize the Maxican banknotes with the precision rate of 97.50 per cent. Ahangaryan, (2012) presented the Persian paper currency recognition by using wavelet and neural network. The accuracy of the developed system are 99.00 per cent. Wu, (2009) applied back propagation (BP) network to recognize RMB 100 yuan banknote orientation. Sajal, (2008) presented real time recognition and sorting Bangladeshi banknotes with the precision rate of 100 per cent. Nishimura, (2009) applied structured neural network to recognize US dollar banknotes. Aoba, (2003) used radial basis function (RBF) to recognize Euro banknotes. Nastoulis, (2006) employed probabilistic neural network (PNN) to recognize Euro banknotes. Takeda, (2003) used neural network to recognize Thai banknotes with the precision rate of 99.45 per cent.

Based on the related works, there are many researches try to develop automatic system to recognize paper currency in various countries. The A+3BRS conducted more than 6,500 ASEAN Banknotes with the neural network method for recognizing them. The details of the system construction are presented in the next section.

III. METHODOLOGY

This part describes the process of analysis and design, which describes the A+3BRS conceptual diagram and system structure chart. The details of each element are described below.

A. System conceptual diagram

The A+3BRS starts with user taking a banknote image by using a mobile-phone digital camera. Then the banknote image is submitted to a computer system for recognizing. After that, the system compares the banknote image with all banknote images in the system database. Finally, the A+3BRS displays the recognition results, as shown in Figure 2.

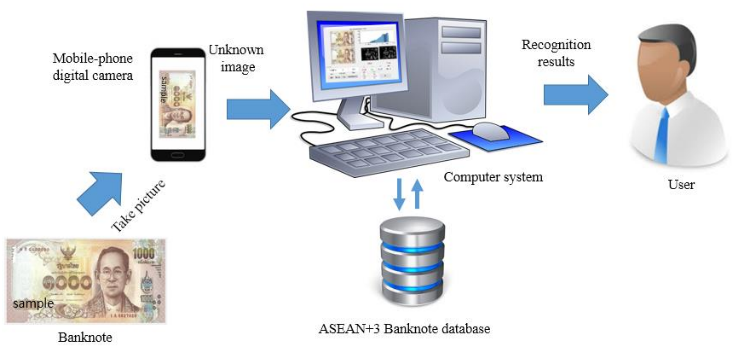

Figure 1. The A+3BRS conceptual diagram.

B. System structure chart

To provide a better understanding and more detail of each operation of the A+3BRS, the system structure chart elaborating on how each model works is shown in Figure 3. The A+3BRS consists of four main process modules. They are 1) image acquisition, 2) image preprocessing, 3) image recognition and 4) displaying results. Each process module has the following details.

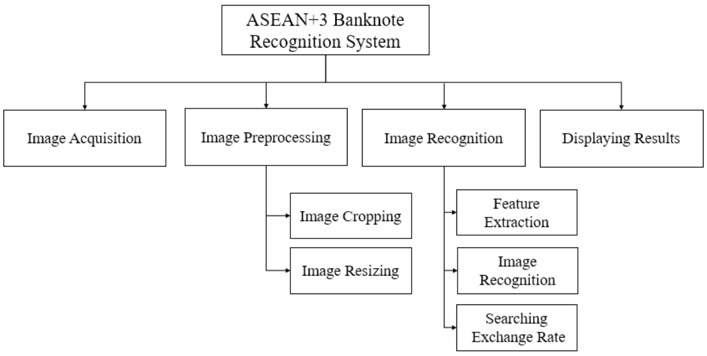

Figure 3

The A+3BRS system structure chart

1) Image acquisition

This module takes ASEAN banknote image from the user mobile phone camera as an input image of the system. A taken image is in a top-view angle as a JPEG file format.

2) Image preprocessing

The image preprocessing module consists of two sub-modules, which are image cropping and image resizing. Each sub-module has the following details.

a) Image cropping

This sub-module is removed unnecessary background noise from the banknote image. The background noise is the serious problem for the banknote recognition system.

b) Image resizing

This sub-module is reduced the banknotes image to an appropriate size, which are 600 * 300 pixels. The system processing time is directly depended on the size of an image.

3) Image recognition

The image recognition module consists of three sub-modules, which are feature extraction, image recognition and searching exchange rate sub-module. Each sub-module has the following details.

a) Feature extraction

The feature extraction sub-module extracted a banknote features. There are four major features, which have the following details.

1) Color features: a color feature is the components of red-green-blue (RGB) in a banknote image.

2) Histogram feature: a histogram is a statistical graph, which ordered gray color on

X-axis and the number of pixels on the y-axis.

3) Edge feature: there are many techniques for finding an image age such as Sobel, Canny, Roberts, Prewitt, Laplacian, Kirsch Compass, Robinson Compass and Frei-Chen. The A+3BRS employed Sobel and Canny edge detection to recognize a ASEAN paper currency.

4) GLCM texture feature: The A+3BRS used Contrast, Correlation, Energy and Homogeneity GLCM feature to recognize the ASEAN+3 banknotes. The details of each GLCM properties are shown in Table 1.

Table 1

Parameters of Texture Feature (Shoeb, (2016))

Property	Description	Formula
Contrast	Measure of the intensity contrast between a pixel and its neighbor over the whole image.	$\sum_{i,j} \lvert i - j \rvert^2 P(i, j)$
Correlation	Measure of how correlated a pixel is to its neighbor over the whole image	$\sum_{i,j} \frac{(i - \mu_i)(j - \mu_j) P(i,j)}{\sigma_i \sigma_j}$
Energy	Sum of square element in the GLCM	$\sum_{i,j} P(i, j)^2$
Homogeneity	Measure the closeness of the distribution of elements in the GLCM to the GLCM diagonal	$\sum_{i,j} \frac{P(i, j)}{1 + \lvert i - j \rvert}$

Where P (i, j) is the (i, j)th entry of the normalized GLCM, μ_i, μ_j and σ_i σ_j denote the mean and SDs of the row and column sums of the GLCM, respectively.

b) Image recognition

The A+3BRS applied the feed forward neural network (FFNN) to recognize the banknote. The structure of FFNN consists of 17 input nodes, 50 hidden nodes and 3 output nodes (as shown in Figure 4). The seventeen input nodes consist of the following features, namely: 1) mean red, 2) mean green, 3) mean blue, 4) contrast, 5) correlation, 6) energy, 7) homogeneity, 8) Sobel-edge of left-top corner, 9) Sobel-edge of right-top corner, 10) Sobel-edge of left-bottom corner, 11) Sobel-edge of left-bottom, 12) Sobel-edge of whole image, 13) Canny-edge of left-top corner, 14) Canny-edge of right-top corner, 15) Canny-edge of left-bottom corner, 16) Canny-edge of left-bottom and 17) Canny-edge of whole image. The three output nodes are 1) running number of banknote in A+3BRS database, 2) the country code and 3) the value of banknote.

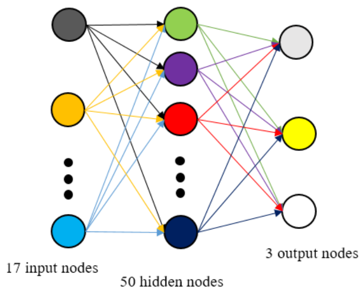

Figure 4

The A+3BRS neural networks structure

c) *Searching exchange rate*

This sub-module is searched the currency exchange rate from A+3BRS database and calculate the currency exchange between Thai baht and ASEAN+3 currency.

4) *Displaying results*

The displaying results module is a graphic user interface (GUI), which illustrates the A+3BRS results on the user screen. The system GUI consists of three components, which are five display windows, thirteen display parameter boxes and four push buttons (as shown in Figure 5). Each component has the following details.

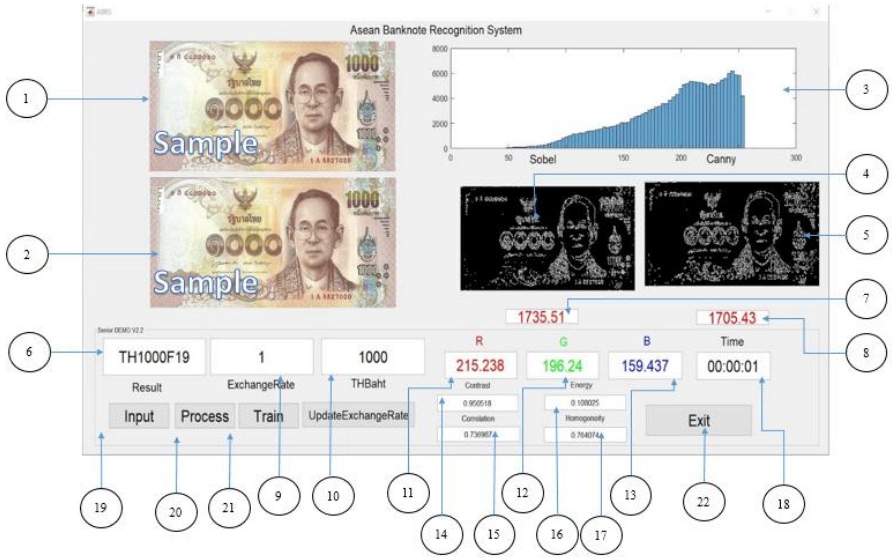

Figure 5

The A+3BRS GUI (graphic user interface)

a) *Display windows*

The display windows have 5 small windows, which illustrate the following images.

1) Input banknote (Label 1, Figure 6)

2) Recognition result banknote (Label 2, Figure 6)

3) Banknote histogram (Label 3, Figure 6)

4) Banknote Sobel edge detection (Label 4, Figure 6)

5) Banknote Canny edge detection (Label 5, Figure 6)

b) Display parameter boxes

There are 13 display parameters boxes, which have the following details.

1) Display banknote input file name (Label 6, Figure 6)
2) Display banknote Sobel edge detection value (Label 7, Figure 6)
3) Display banknote Canny edge detection value (Label 8, Figure 6)
4) Display exchange rate value(Label 9, Figure 6)
5) Display banknote value (Label 10, Figure 6)
6) Display banknote mean red color value (Label 11, Figure 6)
7) Display banknote mean green color value (Label 12, Figure 6)
8) Display banknote mean blue color value (Label 13, Figure 6)
9) Display banknote contrast texture value (Label 14, Figure 6)
10) Display banknote correlation texture value (Label 15, Figure 6)
11) Display banknote energy texture value (Label 16, Figure 6)
12) Display banknote homogeneity texture value (Label 17, Figure 6)
13) display each banknote processing time (Label 18, Figure 6)

c) Push buttons

There are four push buttons, which have the following details.

1) Input banknote push button (Label 19, Figure 6)
2) Process or recognize push button (Label 20, Figure 6)
3) Train the neural network for an unknown banknote (Label 21, Figure 6)
4) Exit the A+3BRS push button (Label 22, Figure 6)

IV. EXPERIMENTAL RESULTS

The experiment conducted on more than 6,500 ASEAN, include with some Chinese, Japanese and South Korean banknotes. The computer hardware used the HP pavilion power 15 and the MSI gp622qe leopard pro. The smart phone camera used the iPhone 5 and the Oppo F1s. The computer software used Microsoft Windows 10 for an operating system (Product id: 00329-00000-00003-AA218), Microsoft Excel 2016 for system database (Product id: 00339-10000-00000-AA287) and MATLAB 2017a (License number 40598465) for the developing program.

The experimental conducted on 598 banknotes images, which are 200 smart-phone images, 221 internet-based images (as shown in Table 2). Moreover, the A+3BRS conducted on the 125 outside ASEAN+3 banknote image and the 50 kid-toy banknote images (as shown in Table 3). The banknote sample image of outside ASEAN+3 countries is shown in Figure 6

(a) and kid-toy banknote images are shown in Figure 6 (b) – (d).

Figure 6

The sample of (a) outside ASEAN+3 banknote (b) – (d) the kids toy banknotes

Table 2

The experimental results of ASEAN+3 banknotes

Country	Smart phone images			Internet-based images		
	Testing Number	Match	Unknown	Testing Number	Match	Unknown
Brunei	23	10	13	15	7	8
Cambodia	13	5	8	5	4	1
China	8	4	4	7	4	3
Indonesia	12	5	7	8	7	1
Japan	12	12	0	6	5	1
South Korea	12	7	5	6	5	1
Lao	19	10	9	46	36	10
Malaysia	4	4	0	3	2	1
Myanmar	17	10	7	3	2	1
Philippine	19	12	7	3	3	0
Singapore	18	8	10	9	8	1
Vietnam	21	7	14	43	34	9
Thailand	22	13	9	67	46	21
Total	200	107	93	221	163	58

Table 3

The experimental results of Outside ASEAN+3 countries and Counterfeit banknotes

Banknote Type	Testing Number	Match	Unknown
Outside ASEAN+3 countries	125	0	125
Kids toy	50	0	50
Total	175	0	175

V. CONCLUSION

In this paper, the A+3BRS fulfilled the research objective by extracting three main banknote features namely: 1) color feature 2) edge detection feature and 3) GLCM texture feature. The color feature consists of three color-features, which are red, green and blue color. The edge detection feature in A+3BRS employs Canny and Sobel edge detection. The GLCM texture in A+3BRS uses four texture-features, namely: 1) contrast, 2) correlation, 3) energy and 4) homogeneity. The A+3BRS trained on 6,500 ASEAN+3 banknote images and tested on 401 ASEAN+3 banknotes, include 125 outside ASEAN+3 banknotes and 25 kids toy banknotes. The precision of the system are 53.50 per cent for mobile phone banknote images (107/200*100), 73.75 per cent for internet-based bank note images (165*100/221), 100.00 per cent for detecting both outside ASEAN+3 countries and kids toy banknotes. The average recognition speed are 0.8563 seconds per image.

There are more than 200 countries around the world. In the near future, to develop all countries banknotes is the target. The banknotes recognition system not only can identify the various countries banknotes but also can transfer the different currency by including the exchange rate table in the system.

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