Mathematical Statistician and Engineering Applications
ISSN: 2094-0343
2326-9865

# Software Development for Distinguishing Counterfeit and Genuine Banknotes Using Histogram Color Distribution

Witthaya Boonsuk*

*Department of Information Technology, Nakhon Phanom University, Thailand, witthaya5773@gmail.com.

**Article Info**
**Page Number: 959-971**
**Publication Issue:**
**Vol. 72 No. 1 (2023)**

***Abstract*** **-** The objective of this research was to develop software to distinguish between counterfeit and genuine banknotes using histogram color distribution. The principles of system design and development is based on the cumulative frequency of the color histogram and the intensity of green and blue. To be used to classify banknotes by analyzing the color from the cumulative frequency of colors in histogram

The results of system proficiency from the testing collected from 5 group samples, 10 images per each group, 50 images in total showed that the precision of group 1: 1,000 Baht banknote was 90%; group 2: 500 Baht banknote was 90%; group 3: 100 Baht banknote was 90%; group 4: 50 Baht banknote was 90%; and group 5: 50 Baht banknote was 90%. Overview of the system considered excellent demonstrated Analyzing the cumulative frequency of the color histogram in conjunction with the chromaticity of the pixels. quite accurate Therefore, it is suitable to be applied in classifying domestic and foreign currency banknotes with this principles in the future.

**Article History**
**Article Received: 15** October 2022
**Revised: 24** November 2022
**Accepted: 18** December 2022

**Keywords:** Histogram; Cumulative Frequency; Image Matching; Graph, Color Index

## Introduction

Today, business transection of daily trading is crucial especially using money in the exchange. It is a necessary part of people's way of life, particularly in businesses. Banknotes are the heart of trading and are popularly used until they are replaced with new currencies. Thus, proofreading or banknote detecting is essential to detect high-value banknotes such as 1,000 and 500 bills. People without expertise cannot distinguish between counterfeit and genuine banknotes. It could vastly affect the economy, trading, and selling products.Therefore, it is essential to apply information technology to work. in counterfeit and genuine banknote analysis. This analysis plays an important role in daily life nowadays. In addition, people in the related business should apply this system to distinguish the banknotes to fasten the decision-making of their business. The use of human resources in management will be less because people cannot examine as thoroughly as the developed system. Therefore, it is possible to use information technology. However, implementation costs may be high at first. It will be worth it in the long run. In the future, information technology has been developed more and more, resulting in lower production costs. The system is an application of group color contribution of histogram graph, histogram image matching, and spatial-color detection [1-2].

Normally, digital images in general use. that we normally see, whether taken with a normal camera or a digital camera for computer Processes images as color points under pixels.[3]. An image histogram is made up of every image pixel representing the cumulative number of colors in the image[4]. Typically, to identify the banknotes, the color comparison is applied to distinguish between the counterfeit and genuine banknotes; however, the precision is not sufficiently precise. Therefore, it is essential to apply cumulative frequency analysis of the histogram colors. in conjunction with pixel chroma because it is more reliable than measuring pixel chroma alone.[5]. Research is being done to improve the histogram similarity measurements for matching algorithms' histograms to be more accurate and clearer for color comparisons.[6]. And there are researches that use other properties such as direct color change techniques to compare colors [7]. And the color contrast ratio technique was used to compare.[8]. Human eye analysis of banknotes has limitations. Viewing requires experience and expertise in distinguishing banknotes. which people cannot do due to lack of experience The researcher has seen the problem and realized the importance of the application of the technology. Therefore, Some researchers have studied and developed algorithms for the application of histograms to improve photographic images by using the cumulative frequency of color histograms to compare images [9]. In addition, the results of this study can be used as a guideline for research and development and can be applied more efficiently in the future.

## Objective

To develop software to distinguish the banknotes using histogram color distribution.

## Materials and methods

*I. Identifying the problem*

The issue is that people generally use money in the business as the medium of trading. The majority of people lack the experience of distinguishing between counterfeit and genuine banknotes. Being able to do so requires the expertise of specialists to analyze colors and textures of counterfeit and genuine banknotes. Due to the limited number of experts, information technology is essential to improve the system. The developed devices and software can save time, and they are convenient for distinguishing between counterfeit and genuine banknotes. The trend of using information technology is increasing in several areas. The development of the devices and software mentioned earlier helps elevate the work capacity, save time, and make life more convenient.

*(a) Five types and values of the banknotes*


**FIGURE 1** 1,000 Baht banknote

Source: https://www.bbc.com/thai/thailand-43327138

**FIGURE 2** 500 Baht banknote

Source: https://www.bbc.com/thai/thailand-43327138


**FIGURE 3** 100 Baht banknote

Source: https://www.bbc.com/thai/thailand-43327138


**FIGURE 4** 50 Baht banknote

Source: https://www.bbc.com/thai/thailand-43327138


**FIGURE 5** 20 Baht banknote

Source: https://www.bbc.com/thai/thailand-43327138

*(b) Analysis of color distribution histogram of 5 types of banknotes*

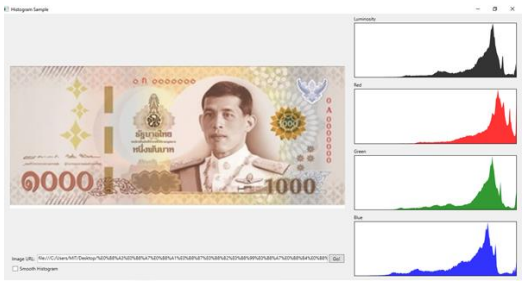


**FIGURE 6** Group color distribution graph of 1,000 Baht banknote

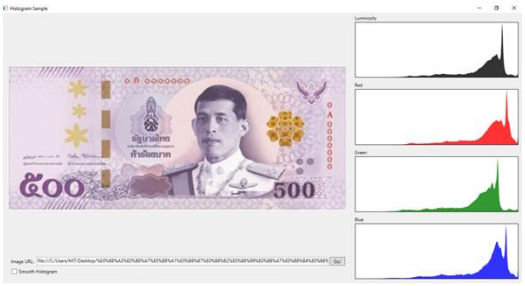

**FIGURE 7** Group color distribution graph of 500 Baht banknote

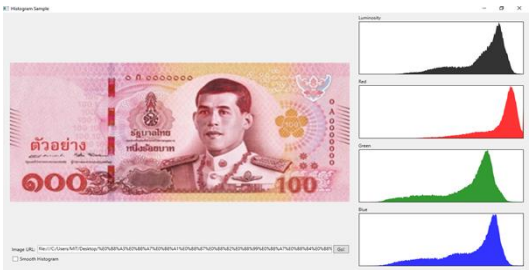

**FIGURE 8** Group color distribution graph of 100 Baht banknote

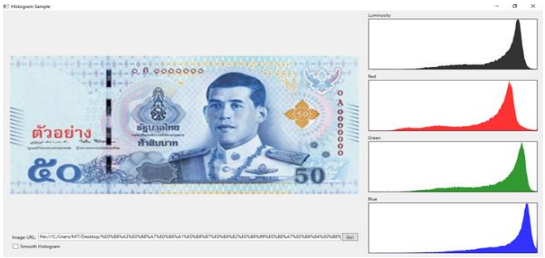

**FIGURE 9** Graph of 50 Baht banknote

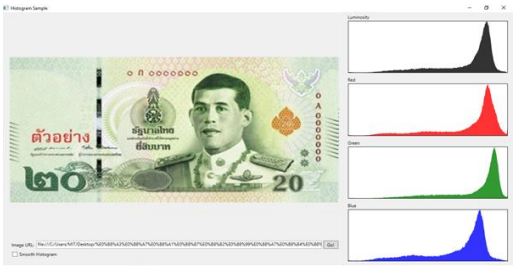

**FIGURE 10** Group color distribution graph of 20 Baht banknote

From Fig. 6-10. graphs of the 3-color distribution of the banknote samples, which were analyzed using histogram color intensity. The analysis showed the color intensity of red, green, and blue had different color intensities that depended on their type and value.

*(c) Finding levels of intensity of 3 colors using histogram graphs of five types of banknotes*

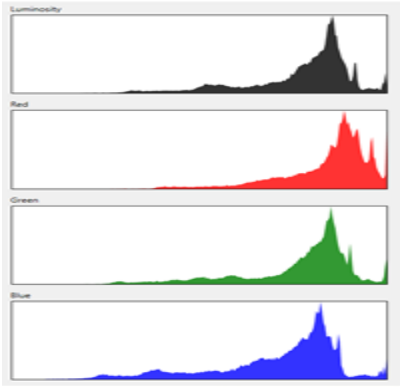


**FIGURE 11** Graph of 1,000 Baht banknote

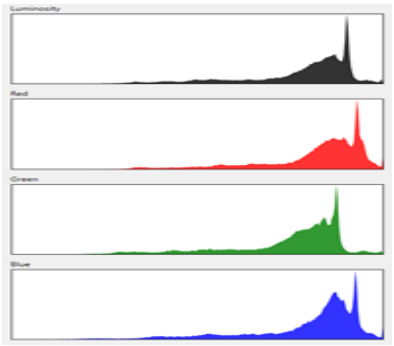


**FIGURE 12** Graph of 500-Baht banknote

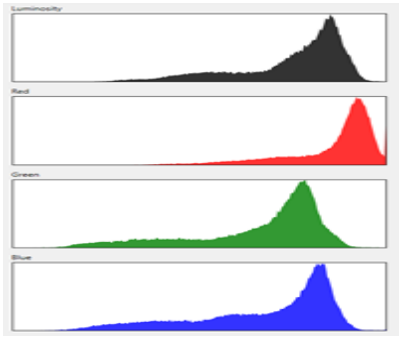


**FIGURE 13** Graph of 100-Baht banknote

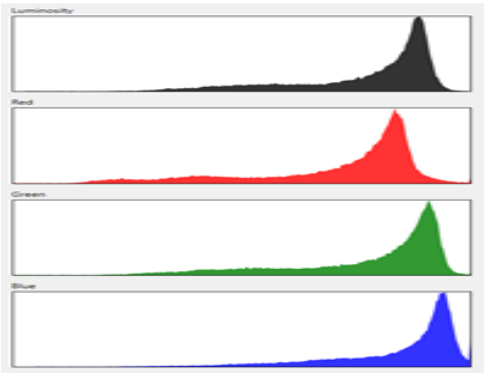


**FIGURE 14** Graph of 50 Baht banknote

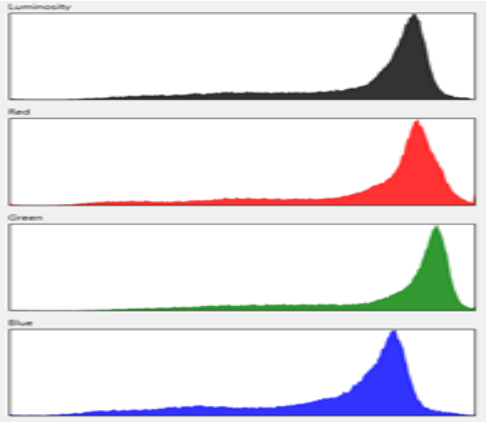

**FIGURE 15** Graph of 20-Baht banknote

Figures 11-15. show the 3-color group distribution of the sample banknotes tested with the color intensity analysis of the histogram. It concluded the intensity level of red, green, and blue colors demonstrated the different changes at a level of 0.255, shown in Table 1.

**TABLE 1** Mean analysis of 5 types of banknotes

| Type of banknotes | Red Average | Green Average | Blue Average |
|---|---|---|---|
| 1,000 | >225 | >210 | >200 |
| 500 | >200 | <220 | >220 |
| 100 | >230 | <200 | <210 |
| 50 | <220 | >230 | >235 |
| 20 | >220 | >230 | <210 |

*II. Analysis of 3-color intensity of 5 banknotes' textures*

*(a) 3-Color intensity of 5 types of banknotes*

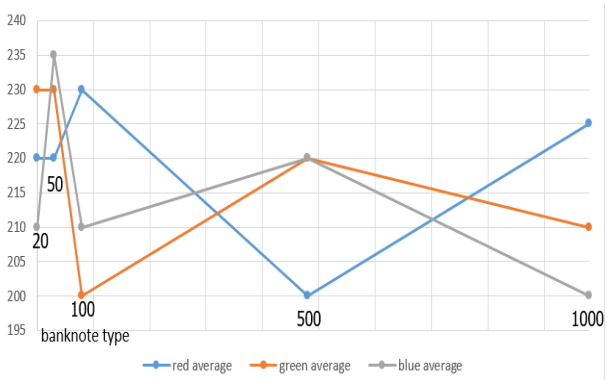


**FIGURE 16** Graph of group color distribution of the banknotes

From Fig.16. the color intensity of the banknotes included three colors: red, green, and blue. Each banknote has a different value depending on its type. For high precision results, five models were used in the system testing and the Algorithm writing.

*(b) Color intensity of five types of banknotes used as image models*

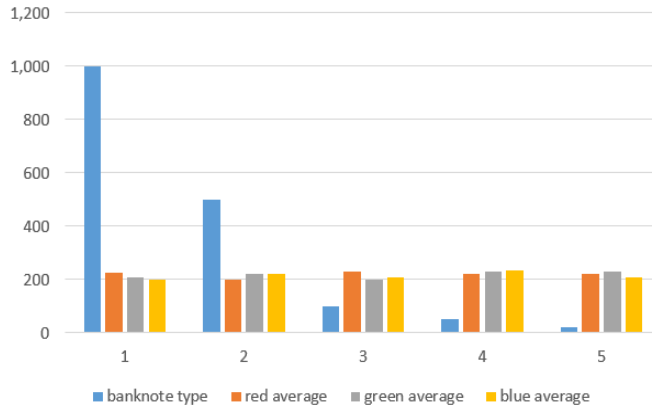


**FIGURE 17** Graphs of group color distribution of the banknotes

From Fig.17. the level of RGB color intensity included three colors: red, green, and blue. Each banknote has a different value depending on its type, presented in Table 1. For high precision results, five models were used in the system testing and the Algorithm writing. [7],[10],[11],[12].

*III. System design*

*(a) Context diagram of a system shown in Figure 18*

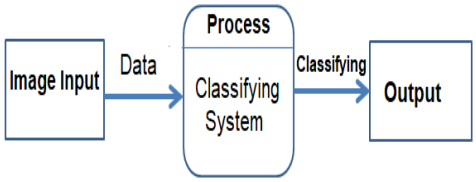


**FIGURE 18** Overview of context diagram of a system

*(b) System structure shown in Fig. 19.*

**FIGURE 19** System structure

*(c) System Flow chart*

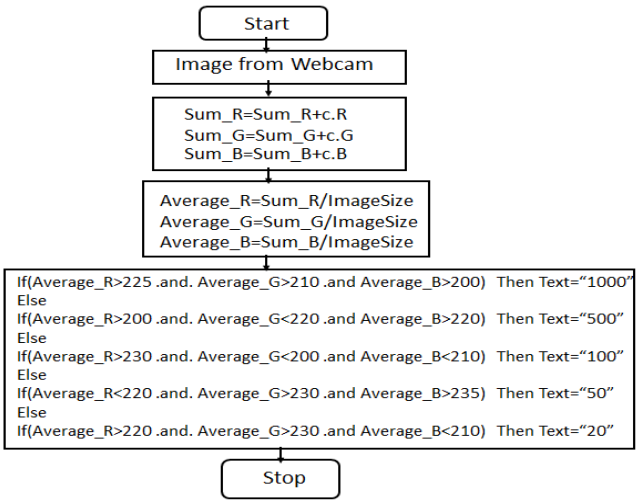


**FIGURE 20** System process

*(d) Algorithm of a system*

```
        for (inti = 0; i<bmap.Width; i++)
        {
for (int j = 0; j <bmap.Height; j++)
{    color  c = bmap.GetPixel(i, j);
Sum_R=Sum_R+c.R
Sum_G=Sum_G+c.G
Sum_B=Sum_B+c.B
Average_R=Sum_R/ImageSize
Average_G=Sum_G/ImageSize
Average_B=Sum_B/ImageSize
        }
       } /End for Loop
If(Average_R>225 .and. Average_G>210 .and Average_B>200)   Then Text="1000"
Else
If(Average_R>200 .and. Average_G<220 .and Average_B>220)   Then Text="500"
Else
If(Average_R>230 .and. Average_G<200 .and Average_B<210)   Then Text="100"
Else
```

If(Average_R<220 .and. Average_G>230 .and Average_B>235) Then Text="50"

Else

If(Average_R>220 .and. Average_G>230 .and Average_B<210) Then Text="20"

Else Text=" Not genuine banknotes "

SpeechSynthesizer synthesizer = new

SpeechSynthesizer(); synthesizer.Volume = 100;

synthesizer.Rate = 0; synthesizer.Speak(text1);

*IV. System design and development*

This research was to develop the classifying system forfive types of banknotes to verify and distinguish five types of banknotes. The Visual C-Sharp was a tool for designing and system development with the user interface. And a webcam to used as an image receiver for the image datasets for the processing.

*(a) Context diagram of a system*

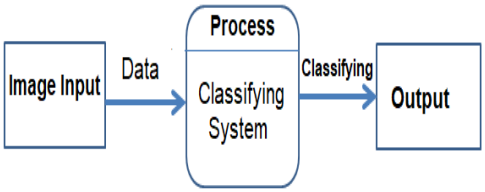


**FIGURE 21** system context diagram

*(b) System structure*

**FIGURE 22** Software Design

Visual C-Sharp program was a tool in the design of model system, the system interface, shown in Fig.22.

*(c) System testing*

The precision proficiency of the color comparison could be measured by the precision value method. This method was the comparison of the genuine banknotes from the database and the datasets considering the color distribution. The process was to find how many images were in

the same group as in the graph distribution and normal standard distribution graph from the database. Moreover, it compared the number of matching banknotes with those in the database then calculated the number, as shown in the equation.[13-15].

$$\text{Precision} = \left| \frac{x_i - x_m}{x_m} \right|$$

$$x_m = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad (1)$$

Xm = Mean

Xi = Value of each measurement

**Results**

*I. Results of system development*

The user interface is shown in Figure 23.

**FIGURE 23** User interface

*II. Results of the assessment of system*

proficiency To assess the system proficiency of cumulative group color distribution of the datasets showed in quantitative and qualitative mean from 5 image datasets retrieving from the database consisted of 50 images.

After the software was tested by using the Black Box method, the following process was to find the system proficiency to meet the acceptance test by the user. The evaluation process was to evaluate IT proficiency and software consisting of 4 parts;

a. Function Requirement Test

b. Function Test

c. Usability Test

d. Security Test

In this case, the emphasis was on the system or software proficiency; thus, the function test criteria were used for regular digital color images. The images of banknotes used were in

*.jpg file type consisting of 50 images with the resolution of 640 x 480 pixels, divided into five groups containing ten images of banknotes per group.

*III. Datasets in system testing*

The 50 images of banknotes used were all in *.jpg file type with the resolution of 640 x 480 pixels, divided into five groups which each group contained ten images of banknotes, shown in Figure 24

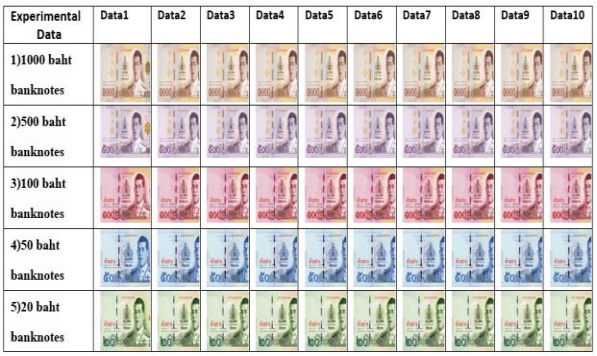


**FIGURE 24** Banknote datasets

From Fig. 24. the datasets of banknotes were tested and analyzed by the developed system. Five datasets included group 1: 1,000 Baht banknote; group 2: 500 Baht banknote; group 3: 100 Baht banknote; group 4: 50 Baht banknote; group 5: 20 Baht banknote. Each dataset contained 10 images, 50 images in total.

*IV. Results*

**TABLE 2** Comparison of the precision of 50 images of banknotes

| Comparison of color intensity levels with those of image datasets. | number of images | Accuracy of color comparison | Average % Accuracy |
|---|---|---|---|
| **1) 1000 baht banknotes** | 10 | 9 | 90% |
| **2) 500 baht banknotes** | 10 | 9 | 90% |
| **3) 100 baht banknotes** | 10 | 9 | 90% |
| **4) 50 baht banknotes** | 10 | 9 | 90% |
| **5) 20 baht banknotes** | 10 | 9 | 90% |
| **Total** | 50 | 45 | 90% |

The precision test of banknotes color was the system that identified the level of color intensity using a histogram graph. The system classified the banknotes models from fifty of banknotes datasets. The pictures were divided into five groups which each group contained ten pictures. The precision of group 1: 1,000 Baht banknote was 90%; group 2: 500 Baht banknote was 90%; group 3: 100 Baht banknote was 90%; group 4: 50 Baht banknote was 90%; and group 5: 20 Baht banknote was 90%. The overview of the system was considered excellent. The result of the new development was the comparison of the banknotes' similarities. was to use the cumulative frequency of the color intensity level to process to find the same level of the number of cumulative frequencies.

## Discussion and conclusion

The findings from the proficiency assessment from the developed Algorithm from the models and the datasets of 50 images with the resolution of 640 x 480 pixels showed that the mean of precision of groups 1 to 5 was 90%, considered excellent. So, the analysis of the cumulative frequency of Histogram color was relatively precise and appropriate to implement in banknote classification for banknotes in good condition. However, for old, faded, or damaged banknotes, the system might affect the lesser precision according to the conditions of the banknotes. However, it should be the comparison of the system with other systems to find the precision and for future application.

## Acknowledgements

This research was successful. The researchers would like to thank Faculty of Information Technology Executives of the Faculty of Management Sciences and Information Technology to support the budget, as well as to support the place, equipment, and time for this research.

## References

1. [1] D. Crandall and J. Luo, " Robust color object detection using spatial - color joint probability Functions, " *Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, USA*, pp. 379–385. 2004.
2. W. Jia, H. Zhang and Q. Wu, "Image matching using colour edge cooccurrence histograms," *Proceedings of the 2006 IEEE International Conference on Systems*, Man, and Cybernetics, page to appear, 2006.
3. K. Wong and C. H. Cheung, "Merged color histogram for color image retrieval," *Proceedings Of the 2002 International Conference on Image Processing*, pp. 949–952, 2002.
4. M. J. Swain and D. H. Ballard, " Indexing via color histograms," *Proceedings of the 3rd International Conference on Computer Vision*, pp. 390–393, 1990.
5. M.J. Swain and D. Ballard, " Color indexing", *International Journal of Computer Vision*, pp.11-32,1991.
6. K.M. Wong, C.-H. Cheung and L.-M. Po, "Merged – Color histogram for color image Retrieval," *Proceedings of the 2002 International Conference on Image Processing*, pp. 949-952, 2002.
7. B. Funt and G. Finlayson, " Color constant color indexing," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol.17 no.5, pp. 522– 529, 1995.
8. T. Gevers and W. Smeulders, "Color constant ratio gradients for image segmentation and similarity of texture objects," *Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, no.1, pp. 18– 25, 2001.
9. H. KaurSohi, "A Study for Applications of Histogram in Image enhancement," *The International Journal of Engineering and Science (IJES)*, Vol. 6, no. 6, pp. 59-63,2017.
10. S. Gupta and Y. Kaur, "Review of Different Local and Global Contrast Enhancement Techniques for a Digital Image," *International Journal of Compute Applications*,vol. 100, no.18, 2014.

11. S.Sapana, B. Vijaya and K. Shandilya, " Use of Histogram Equalization in Image Processing for Image enhancement," *International Journal of Software Engineering Research & Practices*, vol. 1, no. 2. 2011.
12. K. Firdausy, T. Sutikno and E. Prasetyo, "Image Enhancement Using Contrast Stretching on rgb and IHS Digital Image," *Telkomnika*, vol.5, no.1, 2007.
13. J. R. Taylor, "An introduction to error analysis: The An Introduction to Error Analysis The Study of Uncertainties in Physical measurements,"*2nd edition. University Science Books*, pp. 128– 129, 1997.
14. CE. Metz, " Basic principles of ROC analysis," *Semin Nucl Med*, vol.8, pp. 283–298, 1978.
15. X. Wu, " Efficient statistical computations for optimal color quantization," *Graphics Gems*,pp. 126–133, 1991.

## AUTHOR INFORMATION

Witthaya Boonsuk Department of Information Technology, Nakhon Phanom University, Thailand, witthaya5773@gmail.com.