Thai Banknote Recognition Using Neural Network

1055119   SAKOOBUNTHU, Lalita   Takeda Lab.

1.   Introduction

Recently, neural network (NN) algorithm is widely used for pattern recognition because of its abilities of self-organization, parallel processing and generalization [3]. With these 3 abilities, the NN can recognize patterns effectively and robustly. Therefore, the NN has been applied to invent a new recognition system and its hardware using a DSP unit for banknote reader and sorter machines. In recognition processes, there are 3 important steps that are (i) a slab values extraction, (ii) the NN system, and (iii) the DSP application.

In our previous research [3], this proposed system had been applied for various kinds of worldwide banknote such as Japanese Yen, US Dollar and Euro banknote. In this research, a new kind of banknote, Thai banknote (Baht = B) is proposed as the object of recognition. Since, the recognized banknote target is different from the previous research. Therefore, new threshold values for edges detection and a suitable mask set which used for the slab values extraction must be selected again. Generally, Thai banknote has 20 patterns (5 types $\times$ 4 conveyed directions). These 4 conveyed directions are head upright, head reversed, tail upright, and tail reversed. However, in this research, an axis-symmetry mask set has been applied. Then, the total number of patterns, which are recognized, is decreased to 10. Next section, the recognition system overview, the slab values extraction, and the NN system are briefly described. Then, the experimental results are presented. Finally, the DSP application of this system is explained.

2.   Proposed Recognition System

This recognition system consists of preprocesses, the NN system, and the DSP unit as shown in Figure 1. The first part is preprocesses which performed on PC. On the slab values extraction, the slab values, which represented as characteristics of banknote, are extracted from each banknote image by using an axis-symmetry mask set. Then, all slab values are inputted to the NN system for learning and recognition. To confirm the recognition ability of the system before applied for real banking machines, the NN system is firstly performed on PC. Finally, when yield the effective recognition system, all banknote images, an axis-symmetry mask set, and PC converged NN weights are transferred to the DSP unit to execute the NN learning and recognition for the real world system. In this section, all preprocesses and the NN system are described.
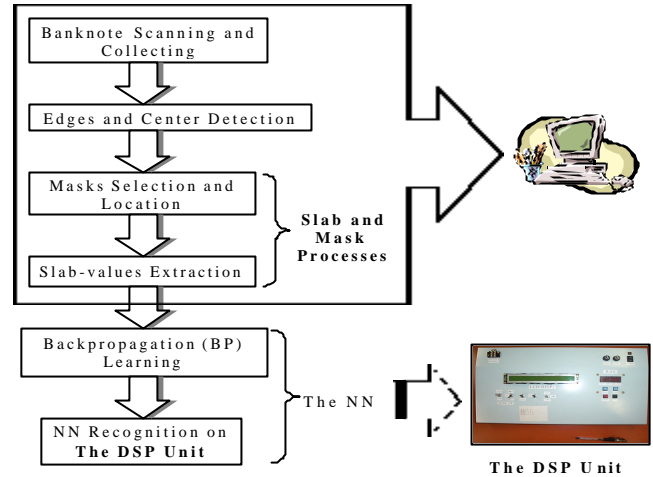

Figure 1   The Recognition System Overview.

2.1. Data Collecting and Edges Detection

The proposed recognition system classifies Thai banknote types from banknote images. Therefore, Thai banknote images are collected as training data for the NN system. To begin, the banknote image is collected by scanner and saved as bit map data. Next, each bit map data is transformed to the NN data format and saved into PC for applying as input to next processes.

Since, a mask set is applied for the slab values extraction, so edges and center of banknote images must be detected to locate the mask. For this detection, 2 threshold values, threshold "cho" and "tan", are manually selected until yield suitable values for all Thai banknote types. These threshold values are offsets of gray scale level projection in long and short side of the banknote. The first and last column (or line) that its gray scale level is more than the threshold values is decided as the edge of banknote image. Finally, banknote center is automatically detected.

2.2. Slabs Values and Axis-symmetry Masks

In this research, the characteristics of each banknote image are slab values that extracted by using an axis-symmetry mask set. This kind of mask set consists of 50 axis-symmetry mask patterns. Thus, each banknote image has 50 slab values and each slab value is summation of non-masked pixel values of each mask pattern. Using the slab values, the NN scale is reduced, which is useful for commercial products, because each pixel value of banknote image is not necessary inputted to the NN. To yield the slab values, firstly, the mask set is manually selected.

Second, center of each mask pattern is located at the same position as the banknote center as shown in Figure 2. Finally, all slab values are extracted and save as database on PC. As a result of using the axis-symmetry mask set, 2 conveyed directions of banknote image are recognized simultaneously (Figure 2). Therefore, total number of recognized patterns for Thai banknote is only 10. Namely, 5 types × 2 conveyed directions (head and tail).
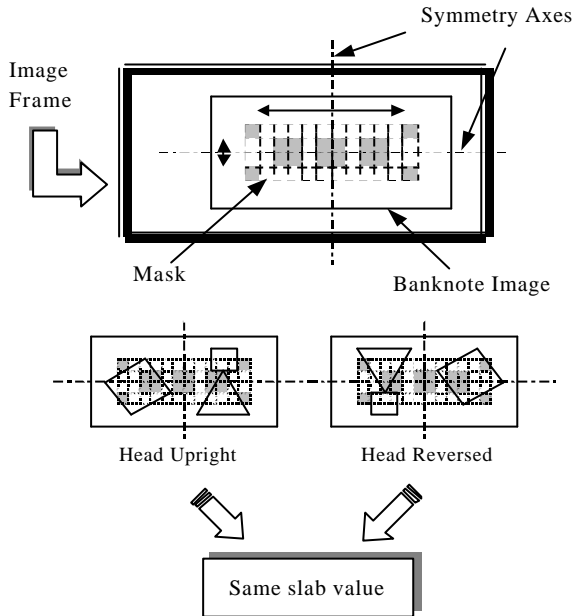

Figure 2   Axis-symmetry Mask and Slab Values.

2.3. Neural Network

In this research, the NN system has 3 layers, input, hidden, and output layer. Table 1 shows the NN structure and learning conditions. Since, one mask set has 50 mask patterns then input nodes number of the input layer is also 50. And the total number of banknote patterns that are recognized is 10 that equal to output nodes number of the output layer. For the NN learning, 20 pieces of each banknote pattern are applied as the training data and its learning algorithm is the backpropagation method. The training data are learned to adjust the NN weights until the error will be reduced below the minimum mean squared error or the iteration number will be reached the maximum iteration number.

Table 1   The NN Structure and Learning Conditions.

Mask no.	50
No. of banknote types	10
Hidden node no.	30
Learning data / pattern	20
Testing data / pattern	80
Mean square error	0.0001
Maximum iteration no.	20000
Learning algorithm	Backpropagation method

3.   Experimental Results

After the NN learning process is completed, the converged NN weights and the mask set are saved in PC and then 80 pieces of banknote image per patterns are tested on PC to evaluate recognition ability by using those NN weights. A recognition ability of all banknote patterns is 100% excepting the 50B head and the 100B head, which their abilities are 95.56% and 98.89%, respectively. Moreover, there is still problem on reliability of the system because of fluctuation of the output response of some patterns. These fluctuations are mainly affected by 2 factors that are (i) the mask positions and (ii) the threshold values for edges and center detection.

4.   DSP Application

To apply this recognition system for real banking system, the DSP unit is proposed. After the system ability was confirmed by testing on PC, all banknote images, the mask set, and PC converged NN weights are transferred to the DSP unit. The DSP unit starts to execute the NN learning again to confirm the converged NN weights and then the recognition process is executed. The NN learning and recognition are performed by NN calculations which saved on flash memory of the DSP unit. By performing the experiment, it seems that the ability of recognition system on the DSP unit is same as the recognition ability of PC experiment.

5.   Conclusion

The NN recognition system with the axis-symmetry mask set for Thai banknote has been proposed and its recognition ability was confirmed by evaluating several pieces of banknotes on both PC and the DSP unit. However, there are some problem in the system reliability because of the output fluctuation by mask set and threshold values. Therefore, in the future, we will improve the threshold-values selection method and apply a genetic algorithm (GA) for mask selection to improve the reliability of this recognition system.

References

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