Parameters Learning of BPS M7 Banknote Processing Machine for Banknote Fitness Classification

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***Abstract*—This paper presents a method to adjust banknote processing machine parameters so that it performance is comparable to the banknote specialist. Using Support Vector Machine to find important factors and select those factors to be adjusted and then find each threshold from individual histogram of each parameters. The result shows that the proposed method can boost classification accuracy to the banknote processing machine.**

Keywords—banknote, fitness classification, banknote processing machine, support vector machine

I. Introduction

Banknote is most popular payment instrument from past till present even if there are lot of alternative payment instruments/channels be more in used. The reason is that banknote is easy to use, it is most acceptable, most private and it does not need any electronic equipment to make a transaction. With this circumstance banknote popularity will remain for a while.

The number of the circulated banknote is massive. Some of them are worn/degraded/deteriorated from daily usage. The number of worn banknotes is proportion to the circulated banknote. This burden is fall to the commercial bank, cash center and central bank. All of them have a duty to take care of and maintain payment system to be fluent and smooth. So they have to process and classify worn banknote to remove them out of the system and replace with the new banknote. The purpose of banknote processing is to maintain a good quality of payment instrument, to have a suitable condition and be pleased to the people who use the banknote.

The problem is that the banknote condition is personal judgement. Different people can have different opinion and admit the cleanliness at different level. As a central bank, we have 2 approaches which are to classify by banknote experts and to classify by banknote processing machine. Those two approaches have some different output which caused by many factors such as humans perceive banknote fitness level through touching and vision, but machine only use a set of simple sensors in various area to determine banknote fitness level.

This research presents banknote classification based on Support Vector Machine (SVM) to find the banknote fitness decision parameter thresholds. The classification model will be applied to set parameters of the banknote processing machine BPS M7.

II. Literature review

Banknote fitness classification research use various method to classify such as using colour of banknote. Artificial Neural Network has been trained to classify banknote soiling level based on histogram. Many methods are different from each other by feature extraction. Examples of the method for classification are shown in Table I. Most of them is summarised from banknote recognition survey [1].

TABLE I. Banknote Fitness classification research

		Method for classification			
		Adaboost	**NN**	**SVM**	**Non-Machine Learning**
Method for feature extraction	**Gray pixel value**	[2]			
	Color pixel value	[2], [4]			[3]
	Pixel values of visible light and NIR images		[5]		[6], [7]
	Gray level histogram		[8]	[11]	
	Mean and standard deviation from ROI by DWT			[9]	
	Acoustic features				[10]
	Refection intensity from spectrophoto meter				[12]
	FED fitness sensors and reflectivity from densitometer				[13]

III. Methodology

A. Banknote features

There are many features on Thai banknote and they serve different purpose. The initial machine-readable features have 210 different values but there are only 21 features that BPS M7 use as fit/unfit banknote decision making. They are as follows.

1. Tape area: Area of plastic tape which stuck on banknote

2. Tear area: Torn area on banknote

3. Fluorescence back: Area of backside banknote which glowed under fluorescent light

4. Fluorescence front: Area of frontside banknote which glowed under fluorescent light

5. Soil Dens: Mean of multi discoloration segment on watermark area

$$\textit{Soil Density} = \frac{\sum_{n=1}^{n} A_n}{n}$$

6. Soil Mod: Standard deviation of multi discoloration segment on watermark area

$$\textit{Soil Mod} = \frac{\sum_{n=1}^{n}(A_n - \bar{A})}{n}$$

7. Defect Max Depth back (Tear/Folded corner): Maximum depth of tears or folded corners on backside

8. Defect Max Depth front (Tear/ Folded corner) : Maximum depth of tears or folded corners on frontside

9. Defect Total Area back (Tear/ Folded corner): Summation area of tears and folded corners to its areas on backside

$$\textit{Defect Total Area back} = \sum_{n=1}^{m} A_n$$

10. Defect Total Area front (Tear/ Folded corner): Summation area of number of tears and folded corners to its areas on frontside

$$\textit{Defect Total Area front} = \sum_{n=1}^{m} A_n$$

11. Hole Total Area: Summation of holes areas

$$\textit{Hole Total Area} = \sum_{n=1}^{m} A_n$$

12. Stain Border back: Stain on outer frame on backside of banknote

13. Stain Border front: Stain on outer frame on frontside of banknote

14. Stain Print back: Stain on area of main picture on backside of banknote

15. Stain Print front: Stain on area of main picture on frontside of banknote

16. Stain White Field back: Stain on watermark area on backside of banknote

17. Stain White Field front: Stain on watermark area on frontside of banknote

18. Foil IR Authentic: Reflected area of foil on banknote under Infrared light

19. Foil Matching check: Similarity check on foil area

20. Folded Corner: Corner of banknote is folded

21. Missed Corner: Disappear of banknote corner

All of the above attributes are used in setting the threshold of the banknote processing machine.

B. Support Vector Machine

SVM is machine learning algorithm which is good at the binary classification. We use this method to classify fit and unfit banknotes according to the BPS M7 readable data. The SVM is a supervised learning type. Users have to train a model with labelled data. In our case the task is to classify group of banknotes to be fit or unfit. The banknotes that have been classified by human experts will be used to train SVM model.

C. Dataset

The experiment is done on 100 Baht Series 16 note.

Number of records: 11,235 notes
Positive records: 5,216 notes
Negative records: 6,014 notes
Number of attributes: 21 features

Fig. 1. Front and back side of 100 Baht Series 16

D. Overview of the Proposed Method

The method used in this research is based on the chart showed on figure 2.

1. Collect banknote – Collect banknotes which are sent from cash center/commercial bank to Central bank.

2. Classified Fit/Unfit banknotes – Bring collected banknotes to be classified of banknote status by banknote experts.

3. Read feature data – Put classified banknotes into banknote processing machine BPS M7 to read all feature data. Repeat Process 2 and 3 for 3 times with 3 different banknote experts then decide each banknote status from majority vote from matching serial number of each banknote.

4. Label the data – Use majority voted banknote status as a label of each banknote.

5. Train machine learning model – Put training dataset to train machine learning model, we choose Support Vector Machine as a classifier and get a banknote fitness classifier model as an output. We use RapidMiner Studio as the machine learning tool.

3. Evaluate model – After getting the output model, we examine and evaluate model by 10 folded cross validation> The metrics are accuracy, precision and recall as a decision maker.

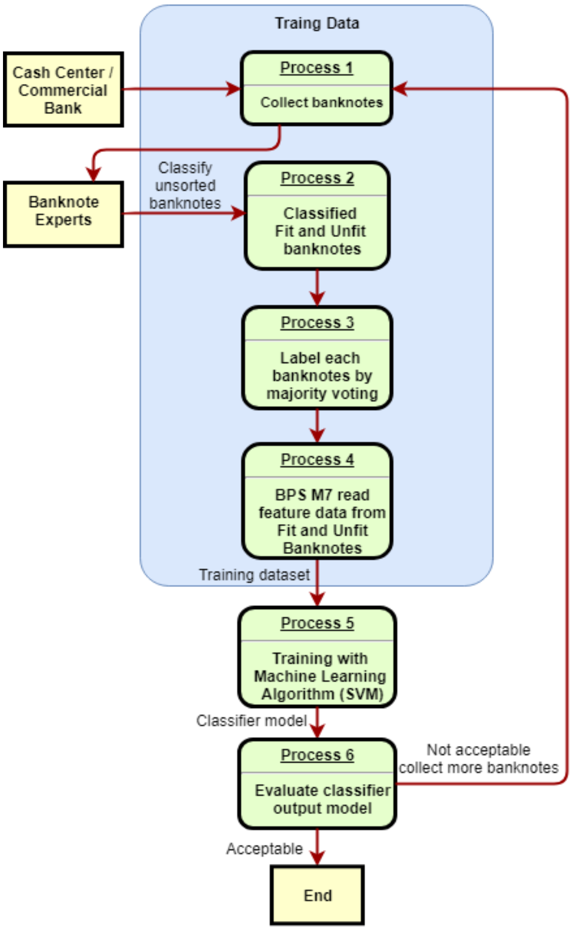

Fig. 2. Process of proposed method

E. *Fitness Classification Using Support Vector Machine in RapidMiner Studio*

In our fitness classification we compare Support Vector Machine and Decision tress and use all the set up as described below (Fig. 3).

Machine Learning process on RapidMiner Studio
Normalization setting: from 0 to 1
Cross validation setting: 10 folds

Parameter grid search for SVM
SVM type: C_SVC
Kernel type: Linear} RBF
C (penalty): 1 to 200 (20 each step)
Gamma (only RBF): 1 to 200 (20 each step)
Epsilon (tolerant): 1 to 200 (20 each step)

TABLE II. SVM GRID SEARCH RESULT

Best combination from C-SVC grid search			Accuracy
Kernel type	Parameters		
Linear	C	140	87.29%
	Epsilon	1	
RBF	C	200	87.51%
	Epsilon	1	
	Gamma	1	

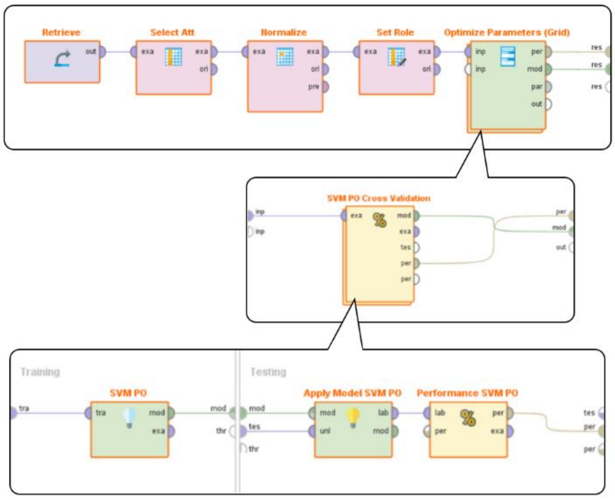

Fig. 3. Diagram of SVM process flow on RapidMiner Studio

IV. EXPERIMENT

After conduct an experiment in RapidMiner Studio the result is shown as below.

A. *SVM confusion matrix*

TABLE III. CONFUSION MATRIX FROM FORMER BPS M7 LOGIC

	True Fit	**True Unfit**	**Class precision**
Predicted as Fit	3400 (30.4%)	563 (5.0%)	85.79%
Predicted as Unfit	1812 (16.2%)	5427 (48.4%)	74.97%
Class recall	65.23%	90.60%	

TABLE IV. CONFUSION MATRIX FROM SVM-LINEAR KERNEL

	True Fit	**True Unfit**	**Class precision**
Predicted as Fit	4621 (41.1%)	833 (7.4%)	84.73%
Predicted as Unfit	595 (5.3%)	5186 (46.2%)	89.71%
Class recall	88.59%	86.16%	

TABLE V. CONFUSION MATRIX FROM SVM-RBF KERNEL

	True Fit	**True Unfit**	**Class precision**
Predicted as Fit	4660 (41.5%)	847 (7.5%)	84.62%
Predicted as Unfit	556 (4.9%)	5172 (46.0%)	90.29%
Class recall	89.34%	85.93%	

B. *Descriptions of Experimental results*

The SVM with RBF kernel gives the highest accuracy. The SVM model shows that the weight of the first 3 feature is the most important. They are: Soil mod, Stain border front and Soil dens respectively.

TABLE VI. SVM LINEAR KERNEL MODEL

Attribute	***Weight***	***Weight proportion***
IR Foil (Ratio reflect area)	256695.5	30.30%
Lead (Foil size)	248607.9	29.30%
Soil mod	128061	15.10%
Soil dens	97840.4	11.50%
Stain Border front	51629.9	6.10%
R UV (rear)	28291.7	3.30%
L UV (front)	26614.5	3.10%
Tear area	2518.9	0.30%
Stain Border back	2303	0.30%
Stain white field back	1506.2	0.20%
RL Defect max depth	469.3	0.10%
Stain Print back	953	0.10%
Stain Print front	720.7	0.10%
RR Defect max depth	466.5	0.10%
Tape area	60.8	0.00%
RL Defect total area	103.3	0.00%
RL Hole total area	22	0.00%
Stain white field front	408.5	0.00%
RR Hole total area	3.4	0.00%
Max folded corner	280.6	0.00%
Max missed corner	246.5	0.00%

V. CONCLUSIONS

SVM banknote fitness classifier can identify banknote fitness more accurately than the former logic in banknote processing machine BPS M7. SVM has improved the accuracy up to 8.71% when compare to the result from banknote experts.

To consider which attribute is important to banknote fitness classification, SVM linear weight model shows that the four most important attributes are IR Foil, Lead Foil, Soil mod and Soil dens. With only the first four attributes, the classifier can identify whether the banknote is fit or unfit with 86.2% accuracy.

The reason behind the four most important attributes found on this 100 Baht S16 banknote sample set is that these attributes are very prominent for human eyes. Foil and dirtiness or soiling level can be observed easily. They recognized these features. The deteriorated foil is clearly lose the reflectivity and soiling obviously made banknote changed to yellowish color which occurs all over banknote area especialy front side. The other features have less weight because other defects are very rare to find on this banknote sample set. If Central bank want to extend the banknote life, the result from this paper suggests that the focus should be on developing both certainty and durable security feature that are soil resistance. The strength of banknote as present is enough to tolerate other defect like tear or hole on banknote.

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