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A Review on the Researches on Determination of Banknote Fitness

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Abstract

Determination of banknote fitness is an important and challenging task, which classifies used banknotes whether are suitable for recirculation or should be replaced by new ones. Many researches on solving this problem have been conducted on various types of banknote, based on using optical sensors and discrimination algorithms. In this study, we give a review on the previous works on banknote fitness classification.

1. Introduction

The development of automatic payment technology, such as in vending machines or automatic teller machines (ATM), has resulted in the important roles of recognizing and classifying currency papers. Banknotes are sorted not only in denomination but also in the fitness for recirculation. There have been researches on solution for fitness classification of banknote on various types of currency. These can be roughly classified into multiple sensor based method and single sensor based one.

In this paper, we make a summary of several previous works on determination of banknote fitness. The paper is organized as follows. First, several researches on banknote fitness determination are introduced in Section 2. The discussions and future works are given in Section 3.

2. Previous Researches on Determination of Banknote Fitness

Most of the researches on automatic banknote sorting use the optical features. In order to capture the features representing fitness of a banknote, these approaches can use single image sensor or the combination of multiple sensors of visible light, infrared (IR) or ultra-violet (UV). Several works in each category are explained in details as follows.

2.1. Multiple sensor based methods

The research on efficient use of banknote since 1953 by the Dutch central bank [1] showed that soil is one of the main reasons that degrade the fitness of banknote for circulation [1], [2]. In the research conducted by Buitelaar [3], the soiling level of Euro banknotes was evaluated by using various sensors and calculating the correlation between the extracted optical features and the level of soil. From the sensors on different sorting machines, the correlations between the reflectance, transmission, spectral response and five levels of fitness are calculated. Though not proposing a solution for automatically classifying banknote, the analysis in [3] gave details about the effects of various factors that reflect soiling characteristic of banknotes such as color channels, illumination types, and spectral response, etc.

In the method proposed by Aoba *et al.* [4], gray-scale visible and IR images were used as input data for classification by three-layered perceptron and RBF networks. This research in fact mostly focused on denomination classification, but took into account the “rejected” cases that imply the unfit banknote. The experimental results showed the acceptance rates for rejected data in both cases of “dirty” banknote and color-copied data (fake banknotes) are 0.0%.

In the fake and destroyed Indian banknote recognizing system proposed by Sanjana *et al.* [5], The various sensors of visible image, UV and IR were used to detect the security features on banknotes, such as watermarks, latent images, and serial numbers, which helps to recognize counterfeit currency notes. In this research, banknote images were partitioned by support vector machine (SVM) and character recognition methods, and the data was trained and tested with artificial neural network (ANN).

2.2 Single sensor based methods

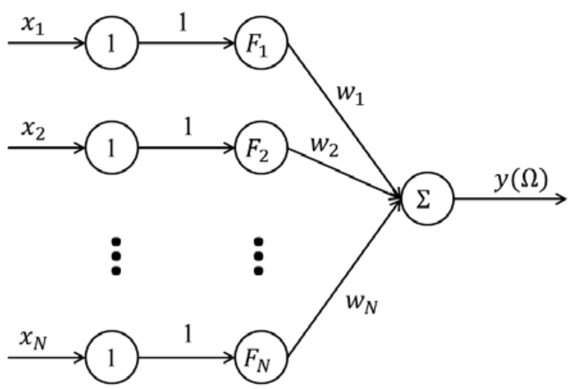
The machine learning method proposed by Geusebroek *et al.* [1] and Balke *et al.* [6] used the color images of Euro banknotes. The fitness measurement features of Euro banknotes are mean and standard deviation of intensity values extracted from overlapping rectangular regions on the channels of banknote images, including intensity, color of R, G, B and color combinations of YB and RG channels. The classifier used in [1] and [6] was combined from simple linear weak classifiers by adaptive boosting (AdaBoost) method. Experiments for their method were conducted on

OeBS dataset and the performance was measured base on calculating the false unfit rates at the accepted false fits of 5%, as shown in Table 1.

<Table 1> Number of data in the OeBS dataset and experimental results for OeBS dataset. False unfit rate at the accepted false fits of 5% [1, 6]

	Training		Validation		False unfit
Denomination	Fit	Unfit	Fit	Unfit	rate
5 Euro	150	150	1348	950	5.5%
10 Euro	150	150	1456	1000	5.1%
20 Euro	150	150	450	633	2.7%
50 Euro	150	150	1397	595	2.6%

In the Chinese banknote classification method proposed by He *et al.* [7], the features of gray level histogram of banknote image were used. In this approach, the dirty level of banknote was defined as a value from 0 to 1, and was estimated by using neural network as illustrated in Figure 1, with sine basis kernel function givens by (1) [7]. Experimental results showed the output of neural network converged to the expected level of banknote.



(Figure 1) Structure of neural network used in [7]

$$F_1(x_1) = \sin(\frac{1}{2}x_1),$$
$$F_2(x_2) = \sin(\frac{3}{2}x_2),$$
$$\cdots$$
$$F_N(x_N) = \sin[(N-\frac{1}{2})x_N] \quad (1)$$

An embedded system approach for Indian currency recognition was proposed by Pathrabe *et al.* [8], focusing on counterfeit banknote detection using features extracted from HSV color space and neural network classifier. Due to the hardware limitation of microcontrollers, the data acquisition and classifying algorithm are simplified.

3. Discussion and future works

In this paper, we provide the summarization of several studies on banknote fitness determination. It can be seen from the previous works that, the usage of multiple sensors can make it easier in classification task since the number of discriminating features can be obtained. However, it leads to complexity in hardware implementation. The single sensor based approaches have advantage in sensor usage but complexity in feature extraction methods and classification algorithms. Based on these analyses of previous studies, we plan to study on our banknote fitness determination method which can overcome the limitations of the multiple sensor based method and single sensor based one.

In order to make the classifier of banknote fitness, the ground-truth data of fitness value on the banknote are usually required. However, it is difficult to measure the ground-truth value because the determination of level of fitness can be affected by the subjective perception of human. So, the determination can be different from the expertness of user in the banknote classification, and objective criterion is necessary for the level of fitness irrespective of the kind of banknote.

In addition, it is difficult to make the binary classification of the fit and unfit data in general. In some cases, the classification of three levels such as fit, normal, and unfit is required. So, the research is also necessary, which can produce the consistent value of fitness level with a same banknote irrespective of multiple trials of data acquisition.

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