Banknote Simulator for Aging and Soiling Banknotes using Gaussian Models and Perlin Noise

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Abstract: In this paper, we propose a banknote simulator that generates aged and soiled banknotes. By analyzing the characteristics of circulating banknotes, we developed Gaussian brightness models for gray level changes of circulating banknotes. In addition, the Perlin noise model was used to simulate soiling. The proposed algorithm was tested using US Dollars (USD) and the experimental results show that the proposed method effectively simulated soiled banknote images from new banknote images.

1 INTRODUCTION

As financial transactions greatly increase, a large number of cash transactions are conducted through automated systems. Financial automation systems are widely used in many applications such as automated teller machines (ATM). These systems perform a number of functions, which include banknote classification, fake banknote detection, etc.

On the other hand, as the circulation period of banknotes increases, the recognition accuracy of aged banknotes decreases. In many cases, ATM software (SW) needs to be upgraded to deal with aged banknotes. However, when new banknotes are introduced, ATM developers also need to develop classification programs based on the new banknotes and all the parameter determinations for ATM SW. Consequently, as more aged banknotes start circulating after several months, ATMs make higher errors in terms of banknote classification and validation. In general, updating the ATM SW is time-consuming and expensive. Therefore, there is a great need for good simulators that can produce street quality banknotes from new banknotes. Some aging effects include soiling, creasing, and edge blurness.

Several authors have studied aged banknotes that were generated using mechanical and chemical circulation simulators. However, there has been little research into simulated circulating banknotes that use image processing techniques.

In this paper, after analyzing the characteristics of aged banknotes, we propose Gaussian brightness models that can be used for banknote aging. Next, we combine the Gaussian brightness models with the Perlin noise model to simulate aged banknotes.

The rest of this paper is organized as follows: Section 2 describes the Gaussian brightness models. Section 3 presents a description of aged banknote synthesis using the Gaussian models and the Perlin noise model, and concluding remarks are drawn in Section 4.

2 GAUSSIAN BRIGHTNESS MODELS

2.1 Datasets

We acquired banknote images of real circulating banknotes with a contact image sensor (CIS). The image resolution was 50 dots per inch (DPI). We used USD 1 banknotes for data analyses and parameter estimations. The total number of banknotes was 2000.

2.2 Observation and Measurement

As the circulation period of banknotes increases, bright areas of banknotes generally become darker, and dark areas become brighter (see Figure 1). Based on this observation, we measured the aging

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level of banknotes using Otsu's threshold. This method separates a banknote image into two groups and calculates the average difference of the two groups. When the difference of the banknote is small, it can be said that the banknote has a low level of soiling. Using the average differences, we classified the dataset into three groups: group A (relatively new), group B (medium aging), and group C (heavily aged).

(a)

(b)

Figure 1: Examples of banknote image (a) new banknote, (b) soiled banknote.

2.3 Gaussian Models for Banknote Aging

First, local registration was applied for the banknote image dataset to a reference banknote (new). After registration, we measured the brightness changes within the dataset.

Figure 2 shows some examples of the brightness distributions of the dataset for three areas whose brightness levels in the reference image range from a bright area, a medium area and a dark area. Although there are some variations, it can be seen that the bright area (more than 128) became darker, while the dark area (less than 80) became slightly brighter. The brightness of the middle area (96-112) showed few changes. We divided the brightness into 13 intervals and modeled each interval using a Gaussian distribution. We repeated this procedure for each of the three groups: group A (relatively new), group B (medium aging), and group C (heavily aged). The parameters (means and variances) of the Gaussian models were computed from the training dataset (see Figure 3).

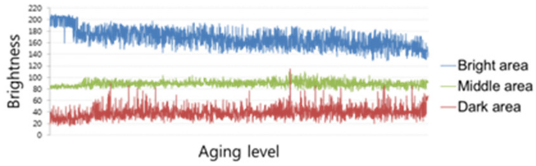
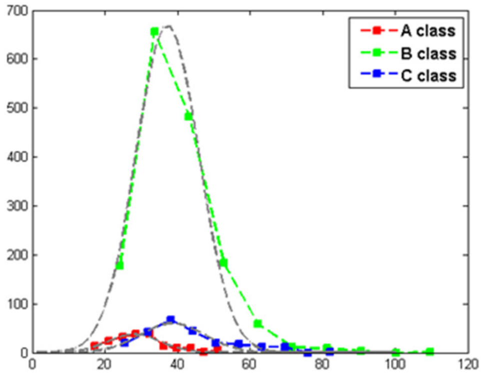
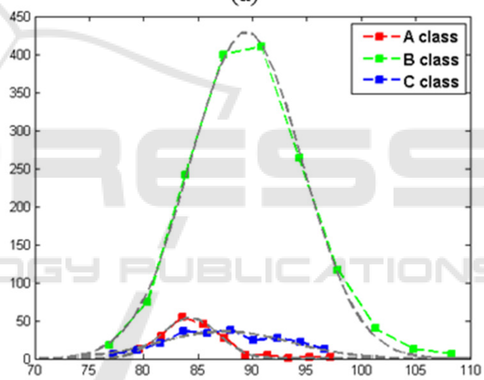


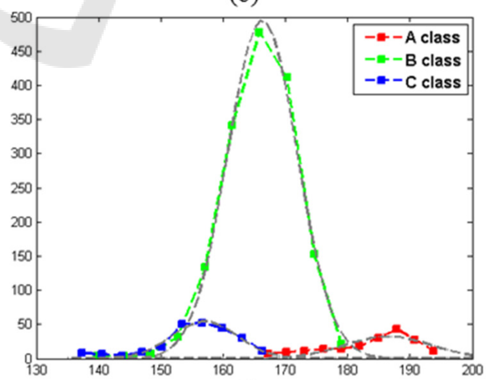
Figure 2: Example of brightness change in circulated banknote.



(a)



(b)



(c)

Figure 3: Histograms of each class (a) dark area, (b) middle area, (c) bright area.

3 SYNTHESIS OF BANKNOTE IMAGES

3.1 Synthesis of Aged Banknotes

Using the Gaussian models, we simulated aged banknotes from new or nearly new banknotes. First, we chose the group (A, B or C) and then determined the degree of aging by randomly selecting the variations of the Gaussian distributions.

We also preserved the correlations between the neighboring pixels of the simulated banknotes. Figure 4 shows an example of an artificially soiled banknote image using the proposed Gaussian brightness modeling.

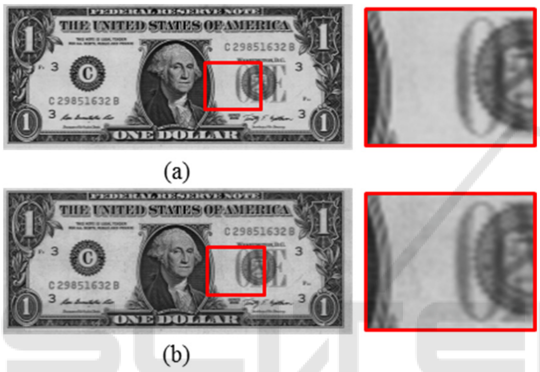


Figure 4: Examples of banknote images (a) real banknote, (b) soiled banknote using Gaussian model.

3.2 Perlin Noise

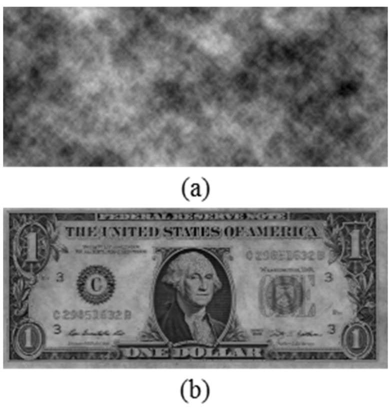


Figure 5: Examples of banknote images (a) Perlin noise map, (b) soiled banknote using Perlin noise.

In order to simulate the natural look of real aged banknotes, the Perlin noise model was used. Perlin noise is a sort of gradient noise, which is rescaled and added into itself to create fractal noise. In the proposed method, the Perlin noise model (eight times scaled synthesis) was used to achieve a natural aging look (see Figure 5). Figure 6 shows examples of generating Perlin noise.

Since brightness changes need to be different depending on the target pixel brightness, Perlin noise was partially applied. In bright areas, Perlin noise was subtracted while it was added in dark areas.

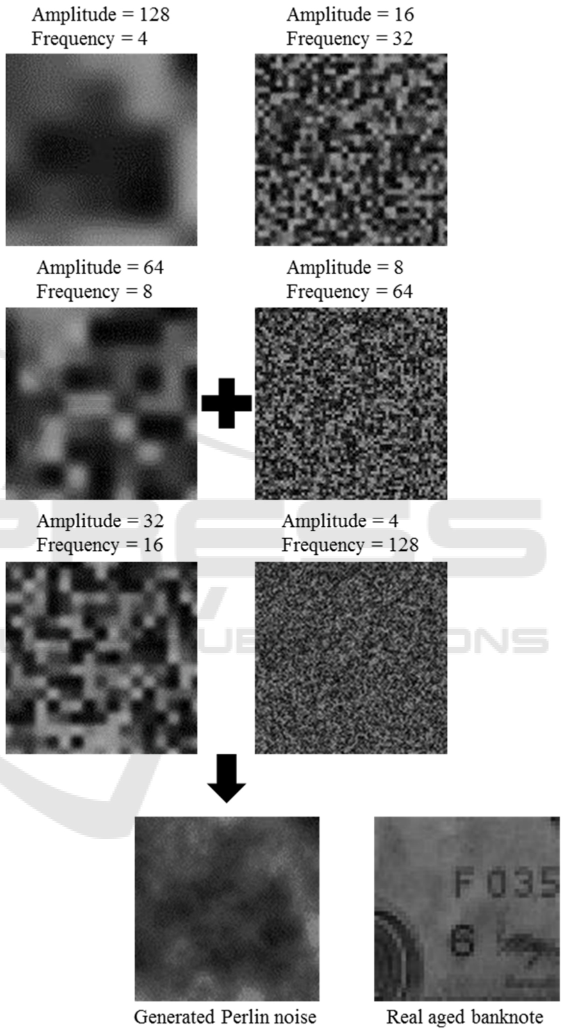


Figure 6: Examples of Perlin noise.

4 CONCLUSIONS

In this paper, we proposed an algorithm to generate artificially aged banknote images. The proposed method is based on the Gaussian brightness model and Perlin noise. The proposed simulator can be used to generate aged banknotes from new banknotes, which can be used to develop robust ATM SW.

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