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De-noising Slap Fingerprint Images for Accurate Slap Fingerprint Segmentation

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***Abstract*—Fingerprints have unique properties like distinctiveness and persistence. Sometimes, fingerprint images can have some noisy data while capturing them using slap fingerprint scanners. This noise causes improper slap fingerprint segmentation due to which the performance of fingerprint matching decreases. The process of eliminating duplicates is called de-duplication which requires the plain quality fingerprints. While doing the segmentation of slap fingerprints, some of the fingerprint images are improperly segmented because of the noise present in the data. In this paper, an attempt is made to remove the noise present in the slap fingerprint data using binarization of slap fingerprint image, and region labeling of desired regions with 8-adjacency neighborhood for accurate slap fingerprint segmentation. Experimental results demonstrate that the fingerprint segmentation rate is improved from 78% to 99%.**

***Keywords*-de-duplication; 8-adjacency neighborhood; slap fingerprint segmentation;**

I. INTRODUCTION

One way of acquiring fingerprints [1] is to capture the slap fingerprint. Slap fingerprints are taken by pressing four fingers simultaneously onto a slap fingerprint scanner. In general, the capturing process will take place in the fashion of 4-4-2 fingers, means capture left four fingers at one time, followed by all right four fingers and then followed by two thumb fingers. The captured slap fingerprints go for the slap fingerprint segmentation which splits the individual fingers from the slap image. The left four fingers slap can be segmented as in the sequence of Left Little (LL), Left Ring (LR), Left Middle (LM) and Left Index (LI). The right four fingers slap can be segmented as in the sequence of Right Index (RI), Right Middle (RM), Right Ring (RR) and Right Little (RL). The two thumb fingers can be segmented as Left Thumb (LT) and Right Thumb (RT). These individual fingerprint images will be submitted for the de-duplication process which will eliminate the duplicates using fingerprint matching. The entire process of de-duplication is carried out in Targeted Public Distribution System (TPDS) in India.

The TPDS is a mechanism for ensuring access and availability of food grains and other essential commodities at subsidized prices to the households. Identification of eligible beneficiaries and ensuring delivery commodities to them effectively and efficiently is the basic challenge for TPDS. The TPDS team has undertaken a project to address the fraud associated with uniquely identifying a household. The main objective of the TPDS project is to find the duplicates by de-duplicating the fingerprints using fingerprint matching which requires the individual fingers. As part of the TPDS project in India, a total of 1.8 million (approximately) slap fingerprint images of 0.6 million (approximately) citizens are captured by a team of pesonnel.

All the captured slap fingerprints undergo slap fingerprint segmentation which is given by a third party vendor. In the process of slap fingerprint segmentation, 22% of the total slap fingerprint images are improperly segmented because of noise present in the data. Moreover, the noise present in the slap fingerprint images are segmented as individual fingers instead of splitting the actual finger. The methods described in [2] - [8], use different filtering techniques to enhance the significant details of single fingerprint images. In this paper, we propose an algorithm to remove the noise present in the images for accurate slap fingerprint segmentation.

This paper is organized as follows. In Section II, the noise removal method for slap fingerprint images is presented. Binarization technique for slap image is explained in Section II-A. Foreground and background segmentation of the slap image is presented in Section II-B. Resampling and region labeling process are explained in Section II-C. Reconstruction of original data for the larger labeled regions is presented in Section II-D. Experimental results and Conclusions are given in Sections III and IV respectively.

II. NOISE REMOVAL METHOD FOR SLAP FINGERPRINT IMAGE SEGMENTATION

The noise removal method uses the noisy slap images. Fig 1 represents the sample noisy four-finger slap image which has the dimensions of 500*dpi* resolution and 1600×1500 image size.

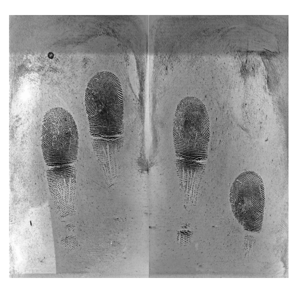

Figure 1. Noisy slap fingerprint image

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The approach to noise removal process is as follows:

1) Binarization of slap image.
2) Foreground and background segmentation of slap image.
3) Resampling and region labeling of slap image with 8-adjacency neighborhood.
4) Reconstruction of the original data for the larger labeled regions of the slap image.

In the following subsections, each of the above steps is explained in detail.

A. Binarization of the slap image

Image binarization is a method of replacing the pixel grey-scale values with a '0' if the pixel grey-scale value is less than the threshold value and replace the pixel grey-scale value with a '255' if the pixel grey-scale value is greater than or equal to the threshold value. Most of the noise which is formed due to the device calibration problem has grey-scale values ranging from 50 to 255. These grey-scale values are replaced with 255 in a way which is similar to binarization. This process of binarization is applied in two different phases: in the phase I, the noise is medium and in phase II, the noise is high. In the phase-I, the threshold is fixed as 100 and the binarization process is carried out on the left over 22% of the slap fingerprint images in TPDS project. In the phase-2, the remaining slap fingerprints images which could not be segmented in phase-I are treated as high noise slap fingerprint images. The threshold value for phase-II is fixed as 50 and the binarization process is carried out on the remaining slap fingerprint images in phase-1. Experimental results are discussed in Section III.

B. Foreground and background segmentation of slap image

In a fingerprint image, the background regions have a very low grey-scale variance value, whereas the foreground regions have a very high variance. In [8], a method based on variance threshold is used to perform the segmentation of foreground and background on the binarized slap fingerprint. In this method, the slap image is divided into blocks and the grey-scale variance is calculated for each block in the image. If the variance is less than the global threshold, then the block belongs to be a background region; otherwise, it is assigned to be part of the foreground. The grey-level variance for a block of size W×W is defined as:

$$V(k) = \left[\frac{1}{W^2}\right] \sum_{r=0}^{W-1} \sum_{c=0}^{W-1} \left(I(r,c) - M(k)\right)^2, \quad (1)$$

where V (k) is the variance for block k, I(r, c) is the grey-level value at pixel (r, c), and M(k) is the mean grey-level value for the block k. The resultant images are shown in Figs 2(k) and 2(l), using a block size of 16×16 and a variance threshold of 100.

C. Resampling and region labeling of slap image with 8-adjacency neighborhood

The resultant slap image after separation of foreground and background is resampled to 160×150 size to reduce the time complexity. The 8-adjacency [9] region labeling process is applied on the resampled slap fingerprint image.

Figs 2(k) and 2(l), illustrate the segmented foreground (other than '0' grey-scale value) and background ('0' grey-scale value) slap images. One dimensional array of label counts is calculated where the index of the array represents label number.

D. Reconstruction of the original data for the larger labeled regions

In the process of binarization, the slap image will lose some genuine data. In order to get the original data, select the labeled regions which have the count greater than 15000 pixels from the one dimensional array of label counts array. The slap image is scanned until the larger region is found. Then, replace all the pixel values in the region which is idenitified by the same label value with the corresponding pixel value from the original image. Figs 2(m) and 2(n) illustrate the noise-free four-finger slap images.

III. Experimental Results

The slap fingerprint database which is collected as part of the TPDS project is used for the experiments. This database consists of 1.8 million slap fingerprint images. The image size is 1600×1500 with resolution of 500*dpi*. It is observed that the correct segmentation rate *Before Noise Removal Process* is 78%, and *After Noise Removal Process*, the correct segmentation rate is 89% in phase-I and it is 99% in phase-II. These results are presented in Table I.

Table I
Segmentation Statistics

	Correct Segmentation
Before Noise Removal Process	78%
After Noise Removal Process (phase-I)	89%
After Noise Removal Process (phase-II)	99%

The images shown in Figs 2(a), 2(c), 2(d), 2(e), 2(f), 2(k), 2(m), 2(o), 2(p), 2(q) and 2(r) belong to Slap-Group-1 and Figs 2(b), 2(g), 2(h), 2(i), 2(j), 2(l), 2(n), 2(s), 2(t), 2(u) and 2(v) belong to Slap-Group-2. It is observed that in the Slap-Group-1, Fig 2(a) represents the slap with high noise. Figs 2(c), 2(d), 2(e) and 2(f) are the segmented fingers of the slap with high noise, which has the NIST Fingerprint Image Quality (NFIQ) scores 3,5,4 and 5 respectively. NFIQ score ranges on the scale 1 to 5, where lesser quality score represents good quality and higher quality score represents poor quality. Fig 2(k) is the resultant image after binarization as well as foreground and background segmentation of the slap fingerprint image. Fig

2(m) shows the noise-free fingerprint image with recovered original data, and Figs 2(o), 2(p), 2(q) and 2(r) are the corresponding segmented fingers with NFIQ scores 1,1,1 and 3 respectively. Similarly, for the Slap-Group-2, It is observed that the accuracy of the slap fingerprint segmentation is improved. These details are given in the Table II where seg-fin-1, seg-fin-2, seg-fin-3 and seg-fin-4 are the four segmented fingers from left to right on the slap fingerprint image.

Table II
NFIQ SCORES FOR SEGMENTED FINGERPRINTS

Segmentation (NFIQ Scores)	Slap-Group-1 Before	Slap-Group-1 After	Slap-Group-2 Before	Slap-Group-2 After
Seg-Fin-1	3	1	5	3
Seg-Fin-2	5	1	4	2
Seg-Fin-3	4	1	4	2
Seg-Fin-4	5	3	5	1

The results shown in Figs 3 and 4 illustrate the levels of segmented fingerprint image NFIQ scores of *Before Noise Removal Process* and *After Noise Removal Process* of the entire dataset, respectively. The NFIQ scale values from 1 to 5 are represented as NFIQ-1, NFIQ-2, NFIQ-3, NFIQ-4 and NFIQ-5, respectively. The X-axis shows the finger positions in the sequence of Right Thumb (RT), Right Index (RI), Right Middle (RM), Right Ring (RR), Right Little (RL), Left Thumb (LT), Left Index (LI), Left Middle (LM), Left Ring (LR) and Left Little (LL). The Y-axis represents the percentages of segmented fingers with NFIQ scores. The requirement for the correct segmentation is defined as the NFIQ scores of all the respective slap segmented fingers should be less than 4. It is observed that the segmenation failure in *Before Noise Removal Process* for the two thumbs is 4%, the failure for the left four fingers slap is 11%, and it is 7% for the right four fingers slap as shown in Fig 3. The currect segmentation rate for the entire dataset is significantly improved to 99% as shown in Fig 4.

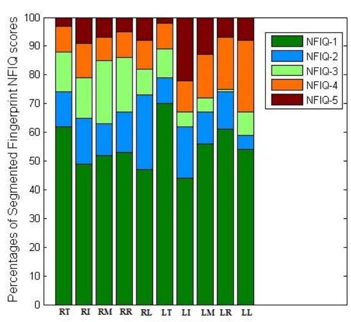

Figure 3. Levels of Fingerprint Image NFIQ scores for the entire dataset - Before Noise Removal Process

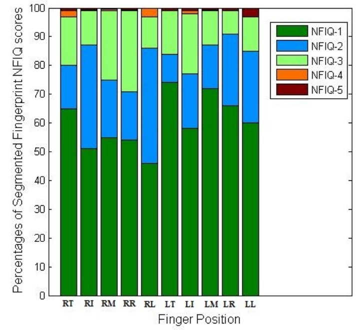

Figure 4. Levels of Fingerprint Image NFIQ scores for the entire dataset - After Noise Removal Process

IV. CONCLUSION

In this paper, a noise removal method is proposed to segment the individual fingers accurately from the slap fingerprint images using third party slap fingerprint segmentation algorithm. The proposed method is used to remove the noise present in the slap fingerprint data using binarization of slap fingerprint image, foreground and background segmentation of slap image and region labeling of desired regions with 8-adjacency neighborhood. The performance of the proposed approach given the slap segmentation rate of 99%.

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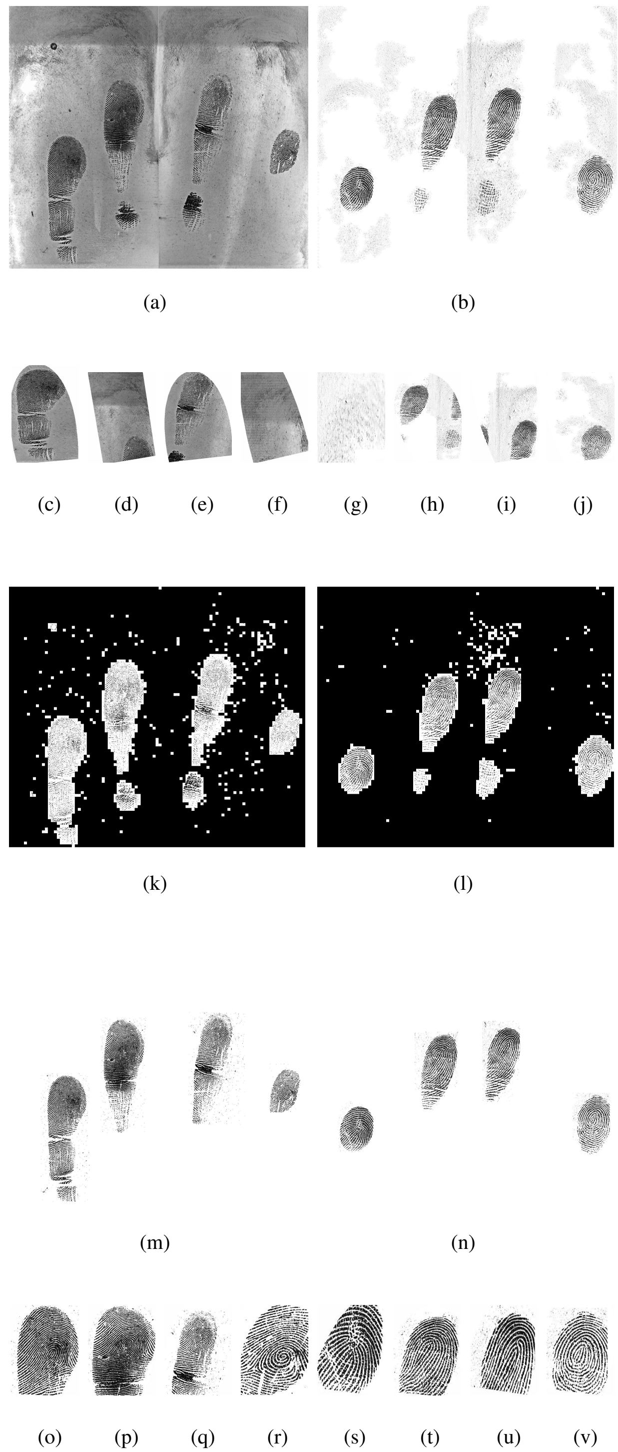

Figure 2. Illustration of Sequence of steps in fingerprint noise removal process: (a) slap with high noise, (b) slap with low noise, (c,d,e,f) are segmented fingers of the slap with high noise, (g,h,i,j) are segmented fingers of the slap with low noise, (k) foreground-background separation of high noisy slap, (l) foreground-background separation of low noisy slap, (m) noise-free slap of high noise, (n) noise-free slap of low noise, (o,p,q,r) are segmented fingers of noise-free slap of high noise, and (s,t,u,v) are segmented fingers of noise-free slap of low noise.