Empirical study on liveness detection of fingerprint

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Abstract

Recent studies show that fingerprint recognition technology is confronted with spoofing of artificial fingers. In order to overcome this problem, the fingerprint recognition system needs to distinguish a fake finger from a live finger. This paper examines existing software-based approaches for fingerprint liveness detection through experiments. Implemented and tested in this paper are the approaches based on deformation, wavelet, and perspiration. These approaches will be analyzed and compared based on experimental results.

1 Introduction

Liveness detection or vitality detection in fingerprint recognition means the capability of the system to detect, during enrollment and identification/verification, whether or not the fingerprint sample presented is captured from a live finger. There are essentially two practical ways to introduce spoof detection into a fingerprint recognition system: one is using extra hardware to acquire life signs such as temperature[1], electric resistance[1], odor[2], optical properties[3]. The other one is based on the image already captured by the sensor to detect life signs such as skin deformation[4], coarseness[5], perspiration[6,7,8], and pores. The main problem with the methods based on extra hardware is that they require additional accessories and may still be fooled by fake fingers once the detection principle is known. Meanwhile, the approaches based on software (image processing techniques) are inexpensive and easy to implement.

The purpose of this work is to study the actual performance of three existing approaches based on software for fingerprint liveness detection. Deformation-based, wavelet-based, and perspiration-based approaches are implemented and tested against silicon fingers.

The rest of this work is organized as follow: a brief study of existing algorithms for fingerprint liveness detection is provided in Section 2. An experimental result of the perspiration is reported in section 3, and section 4 draws some conclusions.

2 Fingerprint liveness detection based on software

The approaches examined in this paper are intrinsically those based on image processing, where difference signs between fake and live fingers are detected by utilizing the information from a still image or a sequence of still images. The difference signs can be the difference of intensity caused by perspiration, the difference of deformation, and the difference of fingerprint image quality.

- **Deformation-based approach**

Antonelli et al.[4]present an approach for discriminating real fingers from fakes, based on the analysis of human skin elasticity. Some preliminary studies showed that the distortion produced by a real finger moving on a scanner surface is quite different from that produced by fake fingers. Usually, fake fingers are more rigid than skin and the deformation is lower.

The main steps of the feature extraction approach are shown in Fig. 1.

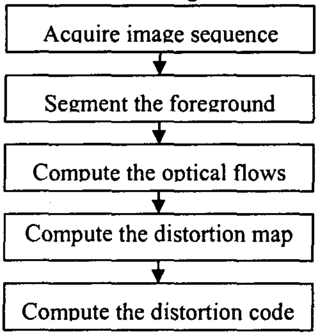

Fig. 1 Flow-chart of the algorithm based on deformation

● **Wavelet-based approach**

The approach described in [5] treats the surface coarseness as a kind of Gaussian white noise added to the images (high resolution). A finger tip image is first de-noised using the wavelet transform. The noise residue (original image subtracted by de-noised image) is then calculated. Coarser surface texture tends to result in a stronger pixel value fluctuation in the noise residue. Thus, the standard deviation of the noise residue can be used as an indicator to the texture coarseness.

The database contains 23 real, 10 gelatin and 24 plastic clay fake finger tips. 200 sub-images were randomly cropped from the database, 100 sub-images are from real, 50 from gelatin, the remaining 50 from plastic clay finger tip images. Matching results are shown in Fig. 2

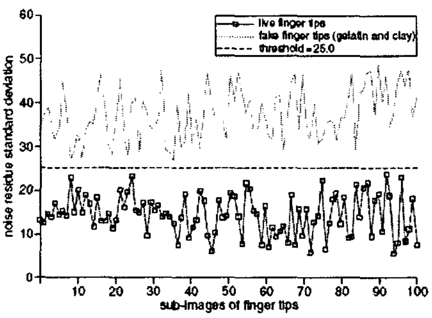

Fig. 2 Experimental results of algorithm based on wavelet[5]

● **Perspiration-based approach**

Derakhahani et al.[6] and Parthasaradhi et al.[7] presented an algorithm which is based on the detection of perspiration in a time progression of fingerprint images. This algorithm focuses on frequencies corresponding to the spatial frequency of the pores and quantifies the change in the local maxima and minima in the ridge signal as dynamic features.

Here are the main steps performed in the algorithm: Firstly, capture a pair of consecutive fingerprints in 5 seconds. Preprocess the image to obtain contours passing through the middle of the ridges. Remove the Y connections (bifurcation), throw away curves shorter than 15 pixels, take this curves as a mask, and convert the gray scales along them into signals for both the first and the last capture. Fourier transform of the signal (Fig. 3) is used to quantify the static variability in gray level along the ridge due to the pores and the presence of perspiration. Secondly, the dynamic features quantify the change in the local maxima and minima in the ridge signal.

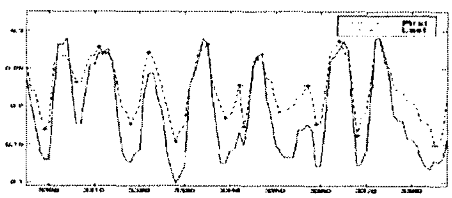

Fig. 3 Portion of a live fingerprint signals[6]

The algorithm develops one static measure and four dynamic measures. Classification can be performed based on each of the individual measures developed. While the individual measures give EERs of between 5.56% and 38.89%, much lower EERs can be achieved by combining all measures. In order to classify the finger as live or fake/dead, a BP neural network is used with the static measure and dynamic measures as input.

Tan, et al.[8] have demonstrated that the time-varying perspiration pattern can be used as a measure to detect liveness for fingerprint systems. They presented two features: static and dynamic features to analyze the detection of the liveness.

The basic steps are listed as follows:

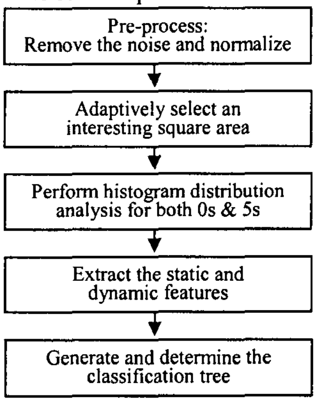

Fig. 4 Algorithm flow chart based on intensity

3 Experiments

Currently, only the algorithm based on perspiration has been implemented. The change of the intensity by the influence of different pressure, and the change of the signal following the ridge line at 0^{th}, 5^{th}, and 20^{th} seconds were observed.

The experiment considers two sensors (Digent, Secutornix), 10 live finger tips and 6 silicon fake finger tips. We acquire 46 sequences of 21 images in 1 second interval. 20 live sequences are acquired at 200 gram (+-15 gram, 10 from Digent, 10 from SecuTornix), 20 other live sequences are acquired at 485 gram (+-15 gram, 10 from Digent, 10 from SecuTornix), and 6 fake sequences are acquired at a constant pressure (Digent).

The algorithm tested in this work is as follows: 1) obtain the sequence and pre-processing; 2) for each image, select an area suitably and accumulate the intensity within the area; 3) compute the difference by subtracting the accumulation of the first (0^{th} second) image from the rest images and plot it (Fig. 5).

In Fig. 5, we can see that the perspiration phenomenon is quite different at 200 gram and 485 gram (Fig. 5 a, b, c, d) constant pressure, a relatively distinct difference on perspiration for most of the sequences at light pressure(Fig. 5 a, c) can be observed.

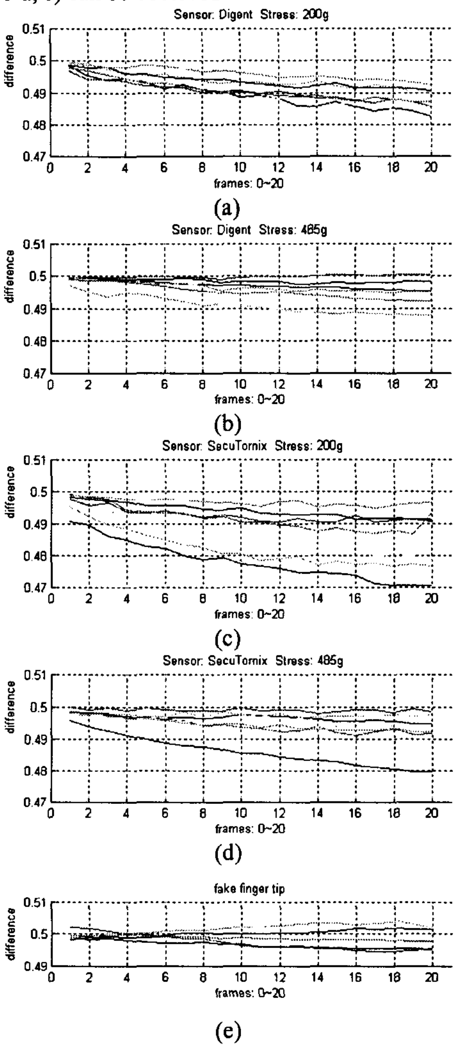

Fig. 5 Experiment of perspiration. (a) data from sensor Digent at 200g; (b) data from sensor Digent at 485g; (c) data from sensor SecuTornix at 200g; (d) data from sensor SecuTornix at 485g; (e) the change of the accumulation of the fake finger tips

However, it is a little different at 485 gram pressure. Some sequences have no change at high pressure, and distinct perspiration phenomenon for most of the sequences can not be observed. And the sequences acquired by the SecuTornix are more diffused than those by the Digent, the characteristic of perspiration depends on that of the sensor too. Liveness fingerprint signals along the ridge line are obtained (Fig. 6). It should be noted that there are small changes on 5^{th} second image, and more changes after five seconds.

The experiment shows that a good effect of the perspiration can be observed at light constant pressure. But in practical scenario, the users will not always present their fingers steadily, so the perspiration can not be measured steadily, that means the perspiration is good algorithm theoretically, but it is difficult to fit in the practical applications.

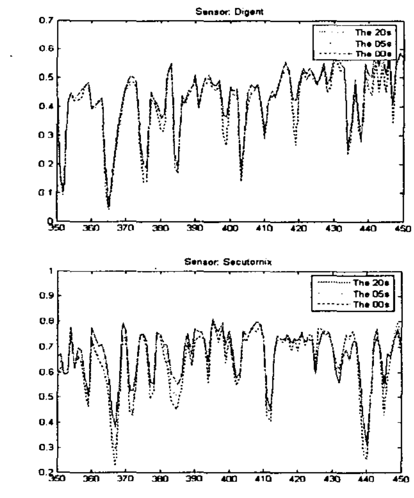

Fig. 7 Portion of a live fingerprint signals

4 Conclusions and future work

This paper studies the existing algorithms proposed to detect the liveness signals based on image processing. The algorithm based on perspiration has been implemented, experiment results show that the perspiration algorithm is too sensitive to the pressure, and is unsuitable for practical application. Therefore, we need more forward-looking practical algorithm or multi-algorithm fusion technique. As for the future work, we think that the frequency transforms and texture analysis based on fingerprint image quality are more promising, and we will do more experiments on wavelet transform and image quality approaches.

Acknowledgments

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