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Network-based Fingerprint Authentication System Using a Mobile Device

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***Abstract*—Fingerprint-based user authentication is highly effective in networked services such as electronic payment, but conventional authentication solutions have problems in cost, usability and security. To resolve these problems, we propose a touch-less fingerprint authentication solution, in which a mobile device's built-in camera is used to capture fingerprint image, and then it is sent to the server to determine the identity of the user. We designed and implemented a prototype as an application on the Android OS, consisting of capture, preprocessing, and matching stages. The experimental results prove that our proposed solution using a smart device is feasible and it also serves to resolve some potential problems in the touch-based fingerprint technology.**

Keywords—Fingerprint Authentication; E-payment; touch-less; network-based; mobile device; Android

I. Introduction

In daily life the usage of credit cards, check card for shopping, bus card, subway card for traveling, student card for library and department, and many kinds of cards for unlimited purposes and so on. A person has to take many cards and has to remember their passwords or secret codes and to keep secure to take with him all time. There is increasing needs for convenient payment. Fingerprint-based user authentication has a long history, and known to be a reliable solution to meet these needs.

An application using fingerprint authentication is called fingerprint payment system. It is used for various kinds of payment system instead of the tension of cards to put with them and to memorize theirs difficult passwords and pin numbers. Fingerprint payment system is much safe and secure and very easy to use and even without using any password or secret codes to remember as compare with previous system like credit card payment system, wireless system and mobile system etc.

Fingerprint payment system allows the consumer to pay with the touch of a finger on a fingerprint scanner. Its providers require completion of a pre-enrollment process in which index fingers are scanned and address and banking information is recorded in an account database [1]. This transactions process reportedly takes a few seconds. The service was launched in United States in 2005 and spread swiftly into worldwide. For example, Walmart, 7-11 and Taobao all support the service.

Current fingerprint payment system adopts the following technical architecture [2]:

The transaction process is as follows:

1) User presses the fingerprints on the fingerprint sensor.

2) The sensor is connected to the POS and sends the users fingerprints directly to the computer system.

3) The similarity of fingerprint data between user and database will be compared.

4) The fingerprint authentication system judges whether the user is authenticated by the similarity and returns the result to the user.

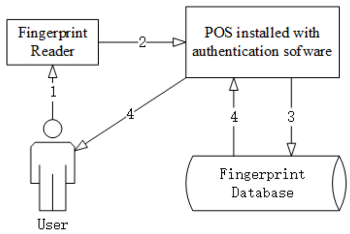


Fig. 1. Current system

However, the seems-good system has the potential problems in three aspects:

First is the cost issue. The sensor is the most critical component of the entire fingerprint recognition process. Recognition is highly dependent on the quality of the captured fingerprint image as in less noise, and better image. Current fingerprint capture method is touch-based. In order to acquire fingerprint images, the touch-based fingerprint sensors require the user to press his finger on the flat window of the sensor. As the sensor's protecting layer is thin, its continuous usage will destroy its surface, making the device useless.

Meanwhile, a set of fingerprint recognition system equipment is expensive and its maintenance expense is cost, for instance software updating and hardware upgrading both cost money.

Second is the usability issue. Current system requires sensor to input users' fingerprints and the system deployment requires a separate terminal hardware and software. Without the specialized hardware, user cannot use this system for payment. The usability is not good enough.

Third is the security issue. After pressing on the surface, a latent fingerprint will be left on it. A latent fingerprint refers to the trail of fingerprint on the surface of the sensor. This can lead to fraudulent use, such as the faking of fingerprints, as well as hygienic problems. Fingerprint left on the reader may also be duplicated by others and applications may leak fingerprint information.

Due to the case above, this paper proposes a network-based finger authentication using a camera. This method is that user uses mobile device's built-in camera to capture fingerprint (FP) image, and send preprocessed FP image to the server through Internet, then the server send back feedback after matches this FP image with initial fingerprint stored in database. The client reacts according to the feedback.

Allowing for smartphone's some advantages: (1) the build-in camera has zooming, auto-focusing and high resolution that is suitable to capture high quality images (2) affordable cost [3] (3) the enough computational capacities to process the photos and execute algorithms, we opted for the smartphone as our experiment tool. There are no extra devices needed to perform the proposed solution. Sending FP and receiving feedback is wireless, just through the Internet, hence, it is convenient. In addition, the capture process is touch-less, so no latent fingerprint is left. Compared with present fingerprint payment system, our method is less cost, stronger usability and much safer.

The rest of the paper is organized as follows. Section II will talk about related works in the touch-less finger recognition. Section III and Section IV will show the basic procedure and detail algorithms. Section V will show experiment results and its analysis. Section VI is our conclusion and future work. The last part of the article is reference.

II. RELATED WORK

To date, several approaches for touch-less fingerprint recognition system have been reported. Application of fingerprint verification technology to mobile handsets is discussed in [4] and a novel method for fingerprint enhancement has been developed for that particular design [5, 6]. In [7], the authors proposed a preprocessing technique which included low pass filtering, segmentation and Gabor enhancement for their own-designed touch-less sensor. Later [8], resolved the 3D to 2D image mapping problem that was introduced in [9] by a strong view difference image rejection method. Preprocessing of fingerprint images captured with mobile camera was suggested by [10]. Most lately, [11] introduced a new touch-less device - The Surround Imager, which can acquire 3D rolled-equivalent fingerprints. To make 3D touch-less fingerprints interoperable with the current AFIS system, [12] proposed an unwrapping algorithm that unwraps the 3D touch-less fingerprint images into 2D representations that are comparable with the legacy rolled fingerprints.

III. PROPOSED SOLUTION

To solve these problems, this paper proposes a network-based finger authentication using mobile device. This method is that user uses mobile device's built-in camera to capture fingerprint (FP) image, and send preprocessed FP image to the server through Internet, then the server send back feedback after matches this FP image with initial fingerprint stored in database. The client reacts according to the feedback.

At first, current smartphone is good enough to capture the finger in sufficient quality and process the photos and execute algorithms for fingerprint recognition. Apart of this, there are no extra devices. And a smartphone is durable to use, so maintenance charge is small.

In addition, network-based system make fingerprint recognition work be done anywhere and anytime. It is much more convenient than the way that you have to go to somewhere and use certain sensor.

The capture process with fingerprint is performed touchless, just use smartphone camera. Hence, no latent fingerprint is left; privacy leak and hygienic problems won't be worried any more.

In general, out proposal solution will cost less, much convenient, and safer.

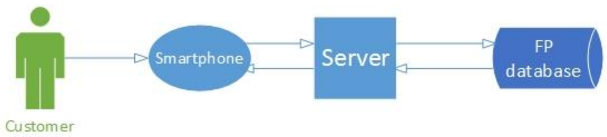


Fig. 2. Proposed solution

IV. IMPLEMENTATION METHOD

Fig. 3 shows our implementation method:

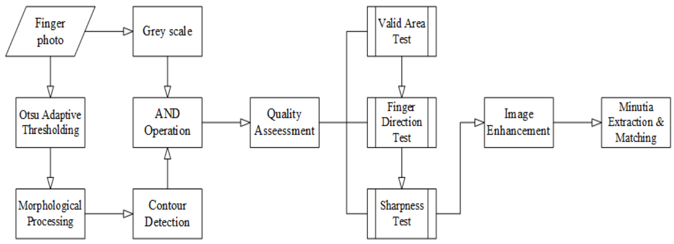


Fig. 3. Proposed implementation method

A. Image Acquisition

The focus is set to "macro mode", such that the camera uses the closest possible focus. The LED is switched on during the capture process. The LED spotlights the finger such that it appears brighter than the background. This simplifies the segmentation of the finger against the background. Another advantage is the reduced camera noise and risk of blurring caused from hand-motion due the high brightness from the LED. The LED also stabilizes the lighting conditions and creates more homogeneous illumination.

Fig. 4. Capture finger with smartphone camera

B. *Foreground Segmentation*

Separating the background is useful to avoid extraction of in noisy areas that is often the background.

1) *Otsu Adaptive Thresholding*.

Through analyzing obtained finger photo's pixels distribution, we find that its histogram contains two classes of pixels (is called bimodal histogram) as shown in Fig. 5. To separate the background is to find a threshold to separate these two classes of pixels. Based on this idea, we choose Otsu's Thresholding Method as first step of this part.

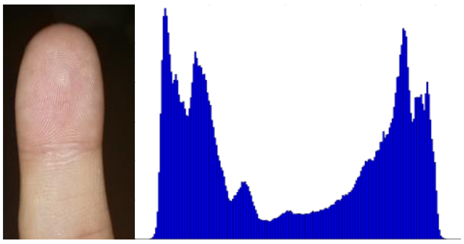


Fig. 5. Finger photo and its grey-scale histogram

Otsu Thresholding algorithm assumes that the image contains two classes of pixels following bimodal histogram, it then calculates the optimum threshold separating the two classes so that their weighted inter-class variance is minimal.

In this way, we exhaustively search for the threshold that minimizes the intra-class variance. Then we covert the grey scale image to binary image according the threshold and successful separate two kinds of pixels classes (Fig. 6).

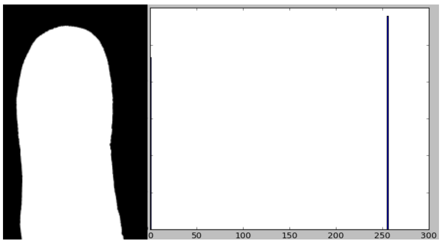


Fig. 6. Otsu binary image and its grey-scale histogram

2) *Morphological Processing*

Mathematical morphology (MM) is useful for the analysis of binary images and common usages include edge detection, noise removal, image enhancement and image segmentation. The two most basic operations in mathematical morphology are erosion and dilation. Erosion is to erode away the boundaries of regions of foreground pixels. Thus areas of foreground pixels shrink in size, and holes within those areas become larger. Dilation is to gradually enlarge the boundaries of regions of foreground pixels. Thus areas of foreground pixels grow in size while holes within those regions become smaller.

After Otsu Thresholding, there may exist some small holes which may result from uneven illumination or pigment deposition (Fig. 7). To fill these holes, we firstly apply dilation operation and then use erosion operation.

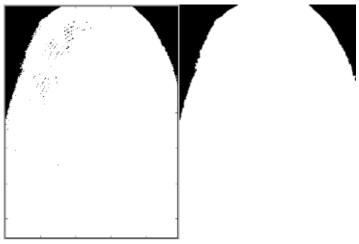


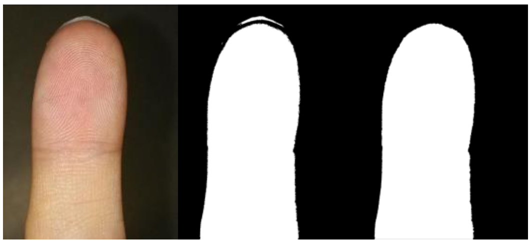
Fig. 7. Unfilled and filled finger photo binary image using 5×5 eclipse kernel

3) *Contour Detection*

It is not enough to segment foreground now, because sometimes finger photo not only contains user's finger, but also some other things, i.e. fingernails. Those background things may wrongly classified into foreground because of their gray scale are similar with finger's part in Otsu Thresholding. It will result in that the foreground area is bigger than real foreground (Fig. 8) and thus foreground is cropped in wrong part.

To solve this problem, we adopt a kind of border following algorithms which was raised by Satoshi Suzuki in 1985. The algorithm is called Topological structural analysis of digitized binary images by border following.

Using this algorithm, we can get all contours in finger binary image processed by Otsu's method. Allowing that the foreground's area is biggest part in the photo, through calculating each contours' point number, we can confirm the finger's contour which has most point number.



(a) (b) (c)

Fig. 8. (a)Original image (b) By Otsu (c) Found contour

4) *Generating mask and bit And operation*

We can generate a mask using gotten contour then segment foreground with it.

Fig. 9. Segmented foreground with generated mask

C. Quality Assessment

This part includes ROI choosing, Valid Area Test, Finger Direction test, Sharpness test.

1) Choosing ROI (Region of Interest)

A region of interest (often abbreviated ROI), is a selected subset of samples within a dataset identified for a particular purpose. In this part, choosing a suitable ROI is critical. An ideal ROI can reduce computation assumption, improve accuracy.

We can find out four direction points in finger contour, which are topmost, bottom-most，leftmost，rightmost and build a white rectangle area. Through many experiments, we set 3/5 rectangle area as our ROI.

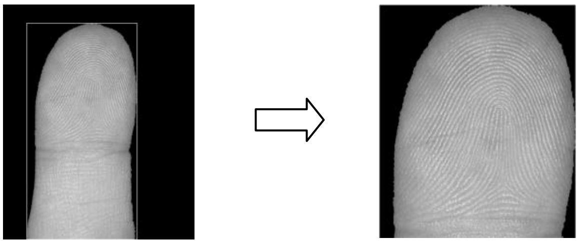


Fig. 10. Rectangle area and ROI

2) Valid Area Test

For some cases, ROI doesn't contain enough details. For example, finger is posed a little of part in front of camera (Fig. 10). We set a minimum area after calculating mean area from many experiments. For each ROI of finger photo, it will be accepted when the ROI exceeds the minimum area threshold.

3) Finger Direction Test

The user is allowed to hold his finger at any desired orientation in the camera. But to compare the feature of two fingers, it is necessary that the finger photos have a uniform orientation. Therefore, an angle of inclination must be calculated. Finding out this angle is a challenge for us. We propose a kind of Linear Least Squares method using finger contours to fit a best approximation line which indicates the finger's direction.

The method's basic idea is to find the best approximation line which minimizes the sum of squared differences between the data values and their corresponding modeled values.

We set a valid angle range, if the resulted angle is in this range, these photo will be taken into consideration.

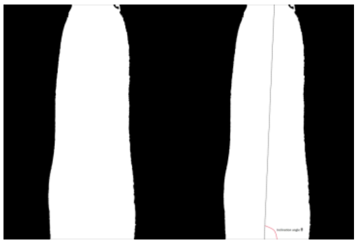


Fig. 11. Using contour to calculate inclination angle θ

4) Sharpness Test

The most important criterion of the quality of a finger photo is the sharpness level, which must be high in order to detect the ridges of the finger. We propose an edge-based approach to determine the sharpness of an image. The Sobel filter is used for this purpose, which calculates the edges (gradient magnitudes) in the image. High-frequent transitions (strong edges) can only appear in sharp images and are clearly visible as bright lines in the edge image. Blurred images do not contain sharp edges and therefore there are almost no visible lines on the edge image. An own defined metric, the"edge density", is used to measure the sharpness in the images, is defined by:

$$density = \frac{1}{M \times N} \sum_{x=1}^{M} \sum_{y=1}^{N} E(x, y) \quad (1)$$

E(x, y): gradient-magnitude of the pixel at position (x, y) in the edge image; M: number of columns of the edge image ; N: number of rows of the edge image

A photo is taken into consideration only when the edge density exceeds an empirically defined threshold

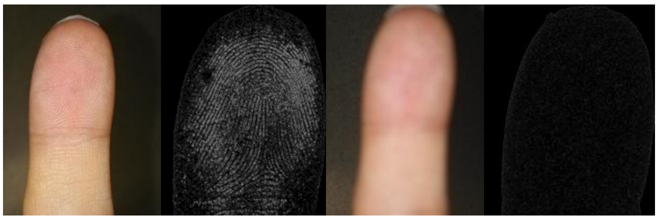


Fig. 12. Clear image with its Sobel edge, blur image with its Sobel edge

D. Image Enhancement

Image enhancement is an important step in fingerprint authentication. It will improve image's visual effect, enhance meaningful information for machine analysis, weaken the useless information, and improve the identification ability.

1) Median Filter

In acquisition procedure, there will easily produce a kind of black and white noise called salt-and-pepper noise from image sensor. We try to eliminate these noises with Median Filter. Because, under certain conditions, it preserves edges while removing noise, it is effective to reduce salt-and - pepper noise.

Fig. 13. Left is origin and right is after median filter

2) CLAHE(Contrast Limited Adaptive Histogram Equalization)

Ordinary histogram equalization may not work well when the image contains regions that are significantly lighter or darker than most of the image, the contrast in those regions will not be sufficiently enhanced. CLAHE differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. It is therefore suitable for improving the local contrast.

Fig. 14. Ordinary HE Vs. CLAHE

3) Binarization and resize

Convert grey image to binary image can not only reduce storage space, but also tell fingerprint's shape in order to improve identification speed. Choosing a good threshold will determine segmentation accuracy, so we adopt Adaptive Thresholding method which threshold is decided by the mean value of neighborhood. An important point is that black line is valley and white line is ridge in the processed image, and the orientation of valley and ridge should be horizontal flipped 180 degrees, which is contrast with ordinary fingerprint we obtain from sensors.

Binarized finger photo always has much very small holes and breakpoints because both ridge and valley skin surface is not flat, uneven illumination or noise still exist. We try to fix these details with median blur.

Because the processed finger photo will finally compared with those fingerprint obtained from touch-based sensor, we resize the finger photo to 357*392 pixels, which is as same as fingerprint size.

E. Minutia Extraction and Matching

The minutiae are extracted from the preprocessed finger foreground area by applying the open source SourceAFIS engine, which provides such service like fingerprint analysis, minutia extraction and similarity comparison. Its FAR is 0.01% and FRR is 10.9%.

When a fingerprint image is submitted to the engine, it will detect only two basic minutia types ridge-ending and ridge-bifurcation. A minutiae pair can be found wen the following criteria are met: The minutiae type is the same and the Euclidian distance as well as the orientation angle of the two minutiae does not exceed the defined tolerance. The comparison subsystem will calculate similarity scores based on these minutiae. The higher the score is, the more similar the two fingerprints are.

Fig. 15. Binarized image and extracted minutia

V. EVALUATION EXPERIMENTS

A. Experiment tools and Database

We use two tools to collect two kinds of finger data. One is smartphone for finger photo; the other is touch-based sensor for fingerprint. The setting and configuration of the smartphone is shown in Table I. The sensor is U.are.U 4500 and its resolution is 500 dpi.

We chose 5 volunteers and collect their index fingers, middle fingers and ring fingers of left and right hands, each finger was sampled five times. We divided these finger data into two classes, F and S, where F means collected by the sensor and S means collected by smartphone. Based on our purpose that using smartphone camera for identification instead of a sensor, we regard the F class as standard fingerprints to be compared, S will be checked by F.

Now our experiment S samples number is 150 and F standard sample number is 150.

TABLE I. CONFIGURATION OF THE SMARTPHONE

Brand	XiaoMi 2s
Image Resolution	3264*2448
ISO Speed	100
Focus Mode	Micro
Flash Light	On
Color Space	RGB

B. Result and Discussion

We compared all sample of S with all of F, so we compared 150*150 times as well as we got 22500 compared results. We set threshold score is 0, it means as long as a result is bigger than 0, the two finger is thought same and identification is successful.

We defined that false reject number is FRN, false accept number is FAN, false reject ratio is FRR, and false accept ratio is FAR.

According to statistics, FRN is 290, FAN is 19, so FRR is 38.66% and FAR is 0.07111%.

We then increase the threshold till to 30, the FRR curve is shown by Fig. 15. When the threshold is set 28, FRR is 41.06%, and FAR decreases to 0.017% which is approximately same with the FAR provided by the designer. We think 28 is an acceptable threshold.

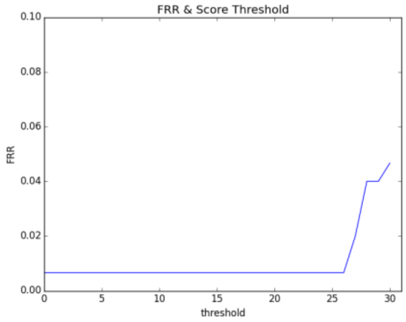


Fig. 16. FRR curve according to threshold score

The reason why the FRR is high is partly that the engine's minutia extraction algorithm was designed to operate on images from optical or capacitive sensors, while we use it to extract finger photo.

Generally, after an image is submitted to the engine, the post-process algorithms will be applied on it for normalization. Normalization is to let the fingerprints have a prespecified mean and variance designed by FBI. This method calls for experience values of mean and variance; however these experience values are suitable for certain situation, not for all. Finger photo is much different with finger image acquired by a sensor, so normalization may make things worse.

In other aspect, we find some clear detail finger photo has low scores, even 0, we think F samples shape are not similar with S samples. Current fingerprint capture method is touch-based. In order to acquire fingerprint images, the touch-based fingerprint sensors require the user to place his finger on the flat window of the sensor. Because the skin of the finger is not flat, the user must apply enough pressure on the window to obtain sufficient size and achieve good image quality. However, this pressure produces unavoidable physical distortion in arbitrary directions, which is represented differently throughout every area of the same fingerprint image. But a finger in finger photo is not distorted. This also may generate bad results.

In addition, after we checked the binary finger images, we find that some photos are over-exposure or uneven illumination, both of these will result in detail lose.

VI. Conclusion and Future Work

The experiment result have proved that our propose method using smartphone for finger authentication is feasible. Use our method can use smartphone camera to replace current fingerprint payment's reader, discard expensive equipment, which will lower cost. Using Internet has make authentication more convenient, improve usability. In addition, because of touchless way, fingerprint won't be left, make it much safer.

Our future work can be divided into four fields:

Firstly, we should solve the over-exposure problem. Here, I come up with an idea, which is we set a brightness test to avoid accepting over-exposure photos. Because the flash LED will make the finger much brighter than unlighted finger, its high grey scale pixels will be more, especially for over-exposure photos. So I wonder whether there exist a grey scale threshold which can decide the photo over-exposure or not.

Secondly, we should research how to recover those low-contrast and bad quality photo, especially for uneven illumination.

Thirdly, auto focus deserves to be researched. We should make the acquisition process much smarter. An ideal process should be like this: once you start to capture finger, the camera will find the best focus point for metering automatically according to the distance between finger and camera. This will improve identification accuracy because it can generate clearer photos.

Fourthly, we should improve security. Based on Network will make user be subjected to attacks from the Internet.

References

[1] Dileep Kumar, Yeonseung Ryu, A Brief Introduction of Biometrics and Fingerprint Payment Technology , International Journal of Advanced Science and Technology Vol. 4, March, 2009

[2] B.Y. Hiew, Andrew B.J. Teoh, Member, IEEE and Y.H. Pang, Digital Camera based Fingerprint Recognition, Proceedings of the 2007 IEEE International Conference on Telecommunications and Malaysia

[3] D. Maltoni, D. Maio, A. K.Jain, and S. Prabhakar, Handbook of Fingerprint Recognition, Springer- Verlag, New York, 2003.J

[4] Rodger Jamieson, Ph.D., CA, Greg Stephens and Santhosh Kumar, Fingerprint Identification: An Aid to the Authentication Process, 2005 Information Systems Audit and Control Association

[5] Jainam Shah*, Ujash Poshiya, Touchless Fingerprint Reorganization, Vishwakarma Government Engineering College, Chandkheda Gujarat, India

[6] M. Hashimoto, S. Tanaka, and J. Thornton, "Biometrics in Mobile Handsets", Technical Report, Mitsubishi Electric Corporation, June 2005

[7] Y. Chen, G. Parziale, E. Diaz-Santana, and A. Jain, "3D Touchless Fingerprints: Compatibility with Legacy Rolled Images", Proceeding of Biometric Symposium, Biometric Consortium Conference, Baltimore,MD, U.S.A, 2006

[8] T. Nakamura, H. Fujiwara, M. Hirooka, and K. Sumi, "Fingerprint Enhancement Using a Parallel Ridge Filter", 17th International Conference on Pattern Recognition 2004, Cambridge, United Kingdom, 2004

[9] C. Lee, S. Lee, and J. Kim, "A Study of Touchless Fingerprint Recognition System", Joint IAPR International Workshops, SSPR 2006 and SPR 2006, Hong Kong, China, 2006

[10] C.H. Lee, S.H. Lee, J.H. Kim, and S.J. Kim, "Preprocessing of a Fingerprint Image Captured with a Mobile Camera ", Advances in Biometrics: International Conference, Hong Kong, China, 2006.

[11] G. Parziale and E. Diaz-Santana, "The Surround Imager: A Multi-camera Touchless Device to Acquire 3D Rolled-Equivalent Fingerprints", IAPR International Conference on Biometrics, Hong Kong, China, 2006

[12] Y. Song, C. Lee, and J. Kim, "A New Scheme for Touchless Fingerprint Recognition System", International Symposium on Intelligent Signal Processing and Communication Systems, Korea, 2004