A Palmprint Cryptosystem

Xiangqian Wu¹, David Zhang², and Kuanquan Wang¹

¹ School of Computer Science and Technology,
Harbin Institute of Technology (HIT), Harbin 150001, China
{xqw, wangkq}@hit.edu.cn
<http://biometrics.hit.edu.cn>

² Biometric Research Centre, Department of Computing,
Hong Kong Polytechnic University, Kowloon, Hong Kong
csdzhang@comp.polyu.edu.hk

Abstract. Traditional cryptosystems are based on passwords, which can be cracked (simple ones) or forgotten (complex ones). This paper proposes a novel cryptosystem based on palmprints. This system directly uses the palmprint as a key to encrypt/decrypt information. The information of a palmprint is so complex that it is very difficult, if not impossible, to crack the system while it need not remember anything to use the system. In the encrypting phase, a 1024 bits binary string is extracted from the palmprints using differential operations. Then the string is translated to a 128 bits encrypting key using a Hash function, and at the same time, an error-correct-code (ECC) is generated. Some general encryption algorithms use the 128 bits encrypting key to encrypt the secret information. In decrypting phase, the 1024 bits binary string extracted from the input palmprint is first corrected using the ECC. Then the corrected string is translated to a decrypting key using the same Hash function. Finally, the corresponding general decryption algorithms use decrypting key to decrypt the information. The experimental results show that the accuracy and security of this system can meet the requirement of most applications.

1 Introduction

Information security is becoming increasingly important in nowadays. Cryptology is one of the most effective ways to enhance the information security. In the traditional cryptosystems, information is encrypted using passwords. The simple passwords are easy to be memorized while they are also easy to be cracked. And the complex passwords are difficult to be cracked while they are also difficult to be remembered. In order to overcome this problem, some biometric feature-based encrypting/decrypting algorithms have been developed [1, 2, 3, 4, 5, 6, 7].

The palmprint is a relatively new biometric feature [8, 9, 10, 11, 12, 13] and has several advantages compared with other currently available features [14]: palmprints contain more information than fingerprint, so they are more distinctive; palmprint capture devices are much cheaper than iris devices; palmprints also contain additional distinctive features such as principal lines and wrinkles,

Fig. 1. An example of the palmprint and the normalized image

which can be extracted from low-resolution images; a highly accurate biometrics system can be built by combining all features of palms, such as palm geometry, ridge and valley features, and principal lines and wrinkles, etc. Therefore, it is suitable to use palmprints to implement a cryptosystem. Up to now, we failed to find any literature to discuss palmprint encryption. In this paper, we will use error-correcting theory to design a palmprint cryptosystem.

When palmprints are captured, the position and direction of a palm may vary so that even palmprints from the same palm may have a little rotation and translation. Furthermore, palms differ in size. Hence palmprint images should be orientated and normalized before feature extraction and matching. In this paper, we use the preprocessing technique described in [13] to align and normalize the palmprints. After preprocessing, the central part of the image, which is 128×128 , is cropped to represent the whole palmprint. Fig. 1 shows a palmprint and the normalized image.

The rest of this paper is organized as follows. Section 2 describes the feature extraction and matching. Section 3 presents the palmprint cryptosystem. Section 4 contains some experimental results and analysis. And Section 5 provides some conclusions.

2 Feature Extraction and Matching

2.1 DiffCode Extraction

Let I denote a palmprint image and G_σ denote a 2D Gaussian filter with the variance σ . The palmprint is first filtered by G_σ as below:

$$I_f = I * G_\sigma \quad (1)$$

where $*$ is the convolution operator.

Then the difference of I_f in the horizontal direction is computed as following:

$$D = I_f * b \quad (2)$$

$$b = [-1, 1] \quad (3)$$

where $*$ is the convolution operator.

Finally, the palmprint is encoded according to the sign of each pixel of D :

$$C(i, j) = \begin{cases} 1, & \text{if } D(i, j) > 0; \\ 0, & \text{otherwise.} \end{cases} \quad (4)$$

C is called DiffCode of the palmprint I . The size of the preprocessed palmprint is 128×128 . Extra experiments shows that the image with 32×32 is enough for the DiffCode extraction and matching. Therefore, before compute the DiffCode, we resize the image from 128×128 to 32×32 . Hence the size of the DiffCode is 32×32 . Fig. 2 shows some examples of DiffCode. From this figure, the DiffCode preserves the structure information of the lines on a palm.

Fig. 2. Some examples of DiffCodes. (a) and (b) are two palmprint samples from a palm; (c) and (d) are two palmprint samples from another palm; (e)-(h) are the DiffCodes of (a)-(d), respectively.

2.2 Similarity Measurement of DiffCode

Because all DiffCodes have the same length, we can use Hamming distance to define their similarity. Let C_1, C_2 be two DiffCodes, their Hamming distance ($H(C_1, C_2)$) is defined as the number of the places where the corresponding values of C_1 and C_2 are different. That is,

$$H(C_1, C_2) = \sum_{i=1}^{32} \sum_{j=1}^{32} C_1(i, j) \otimes C_2(i, j) \quad (5)$$

where $\otimes$ is the logical **XOR** operation.

The matching distance of two DiffCodes C_1 and C_2 is defined as the normalized Hamming distance:

$$D(C_1, C_2) = \frac{H(C_1, C_2)}{32 \times 32} \quad (6)$$

Actually, $D(C_1, C_2)$ is the percentage of the places where C_1 and C_2 have different values. Obviously, $D(C_1, C_2)$ is between 0 and 1 and the smaller the matching distance, the greater the similarity between C_1 and C_2 . The matching score of a perfect match is 0. Because of imperfect preprocessing, there may still be a little translation between the palmprints captured from the same palm at different times. To overcome this problem, we vertically and horizontally translate C_1 a few points to get the translated C_1^T , and then, at each translated position, compute the matching distance between C_1^T and C_2 . Finally, the final matching distance is taken to be the minimum matching distance of all the translated positions.

3 Palmprint Cryptosystem

In general, the palmprints captured from the same hand at different time are not exactly same. However, they are similar enough to distinguish that they are from the same hand. That is, when the matching distance between the DiffCodes C_1 and C_2 is less than a threshold T , they should be regarded as being computed from the same hand, and C_2 should be able to decrypt the information which is encrypted using C_1 . However, in general symmetric cryptosystems (eg. AES), it is impossible to successfully finish the decryption if the encrypting key and the decrypting key are not exactly same. To overcome this problem, we must transform C_2 to C_1 before using it for decryption. Since both C_1 and C_2 are binary strings with the same length, we can use the error-correct-coding theory to encode C_1 and get its error-correcting code, which can correct less than $T \times 1024$ errors, and then use this error-correcting code to correct C_2 . If the matching distance between C_1 and C_2 is less than T , which means that C_1 and C_2 are from the same hand, C_2 can be exactly transformed to C_1 using the error-correcting code. And then the corrected C_2 can be used for decryption.

The principle of the palmprint cryptosystem is shown in Fig. 3. In the encrypting phase, the $32 \times 32 = 1024$ bits DiffCode is extracted from the palmprints. Then the DiffCode is encoded to a fix length palmprint key (HC) using a Hash function (eg. MD5), and at the same time, an error-correct-code (ECC) of the DiffCode is generated using an existed algorithm (eg. BCH). Some general encryption algorithms (eg. AES) use this palmprint key to encrypt the secret information S . In decrypting phase, the 1024 bits DiffCode extracted from the input palmprint is first corrected using the ECC. Then the corrected string is encoded to a palmprint key (HC) using the same Hash function. Finally, the corresponding general decryption algorithms use this key to decrypt the information (S).

To overcome the translation problem, we can get the 144×144 central part of the palmprint in the preprocessing of decryption phase, and then resize it to 36×36 to compute DiffCode. That is, in decryption phase, we get a DiffCode

(a) Encrypting Phase

(b) Decrypting Phase

Fig. 3. Palmprint cryptosystem

with 36×36 size. From this larger DiffCode, we can get 25 DiffCodes with 32×32 , which are used one by one for decryption until success. This process is equivalent to the translation the DiffCode vertically and horizontally from -2 to $+2$ points.

4 Experimental Results and Analysis

We employed the PolyU Palmprint Database [15] to test our system. This database contains 7,752 grayscale images captured from 386 different palms by a CCD-based device. These palmprints were taken from people of different ages and both sexes and were captured twice, at an interval of around two months, each time taking about 10 images from each palm. Therefore, This database contains about 20 images of each palm. The size of the images in the database is 384×284 . In our

experiments, all images were preprocessed using the preprocessing technique described in [13] and the central 128×128 part of the image was cropped to represent the whole palmprint. In the system, the Hash, error-correcting and encrypting algorithms are respectively selected as MD5, BCH and AES.

For a (n, k, t) BCH code, n , k and t respectively mean the length of the code, the length of the information and the number of the errors which can be corrected by this code.

For our system, t can be computed using its distance threshold T as following:

$$t = 1024 \times T. \quad (7)$$

And k should satisfy the following conditions:

$$k \geq 1024 \quad (8)$$

If $k > 1024$, we can append $(k - 1024)$ zeros to the 1024 bits DiffCode to get the message with length k and then encode it using BCH encoding.

Therefore, to error-correcting encoding, we should know the distance threshold of the system, which is dependent on the application. To investigate the relationship between the threshold and accuracy, each sample in the database is matched against the other palmprints in the same database. The matching between palmprints which were captured from the same palm is defined as a genuine matching. Otherwise, the matching is defined as an impostor matching. A total of 30,042,876 ($7,752 \times 7,751/2$) matchings have been performed, in which 74,086 matchings are genuine matchings. The FAR and FRR at different thresholds are plotted in Fig. 4. Some typical FARs, FRRs, the corresponding thresholds and the numbers of the error bits are listed in Table 1. We can select a threshold according to the requirement of the applications.

In our experiments, we choose the distance threshold as 0.2949. According to Table 1, the corresponding FAR, FRR and the number of errors which should be corrected are 0.0012%, 3.0169%, and 302. According to the theory of BCH error-correcting-code, (4095, 1412, 302) BCH code can be used in our system. Now we analyze the attacks to this system.

If the attack happens at Point A (See Fig. 3), that is, the attacker uses some palmprints to attack the system. In this case, the possibility to successfully decrypt the message is about $0.0012\% \approx 10^{-5}$, which means that to decrypt the message, a cracker has to find about 10^5 different palmprints to try, which is very difficult to get so many palmprints in a short time.

If the attack happens at Point B (See Fig. 3), that is, the cracker attacks the system by directly generating the DiffCode for the error-correcting. The possibility to successfully decrypt the message in this way is p :

$$p = \frac{C_{1024}^{302} + C_{1024}^{301} + \cdots + C_{1024}^1 + C_{1024}^0}{2^{1024}} \approx 2^{-134} \quad (9)$$

If the attack happens at Point C (See Fig. 3), that is, the cracker generates the corrected DiffCode to attack the system, the possibility to success is 2^{-1024} .

If the attack happens at Point D (See Fig. 3), that is, the cracker generates the hashed code to attack the system, the possibility to success is 2^{-128} .

Fig. 4. The FAR and FRR at Different Threshold

Table 1. Typical FAR, FRR, coresponding thresholds and number of error bits

Threshold	Number of Error Bits	FAR (%)	FRR (%)
0.3799	389	2.6862	0.0240
0.3750	384	2.0133	0.0283
0.3701	379	1.4784	0.0382
0.3652	374	1.0976	0.0523
0.3604	369	0.7799	0.0764
0.3555	364	0.5458	0.1018
0.3496	358	0.3786	0.1386
0.3447	353	0.2558	0.2150
0.3398	348	0.1663	0.2899
0.3350	343	0.1092	0.3791
0.3301	338	0.0663	0.4964
0.3252	333	0.0399	0.6973
0.3203	328	0.0238	0.9038
0.3154	323	0.0135	1.2277
0.3096	317	0.0075	1.5445
0.3047	312	0.0042	1.9533
0.2998	307	0.0022	2.4370
0.2949	302	0.0012	3.0169
0.2900	297	0.0006	3.6788
0.2852	292	0.0003	4.4751

5 Conclusions

This paper proposed a almpoint cryptosystem. This system extracted binary DiffCode feature from palmprint and used the error-correcting theory to remove

the difference between the DiffCodes from the same palms. The system can effectively encrypt and decrypt messages and it is almost impossible to crack it.

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