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Cancellable Face Recognition System Based on Bit-string Representation

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Abstract: A cancellable face recognition system needs a method to restore templates from facial images for matching even if the templates have been stolen. In this study, we proposed a face recognition scheme using bit-string representation of facial features, so that, templates can be reconstructed. Bit-string representation enables rapid matching and also is useful for applications that require binary data such as biometric cryptosystems. First, we selected several images of the same person and made a 'standard face' of that person by mixing his/her images. Then, from the standard face of several people we made a standard face for that group. Finally, comparing a certain person with the standard face of the group, we extracted bit-string representation for the person. Moreover, when the bit-string was exposed by accident, it could be restored by changing the standard face of the group. In an experiment with the Yale Face database we showed that, using our proposed method, our cancellable face recognition scheme based on bit-string representation worked appropriately.

Key words: Cancellable face recognition system, bit-string representation, biometric cryptosystem, appropriately, representation, scheme

INTRODUCTION

Several well-known algorithms have been used for face recognition: principal component analysis (Turk and Pentland, 1991), independent component analysis (Bartlett *et al.*, 2002) and linear discriminant analysis (Belhumeur *et al.*, 1996; Lu *et al.*, 2003). Another recent method is the three-dimensional (3D) face-recognition approach but it is insensitive to illumination and head pose (Bowyer *et al.*, 2004). Also, the liveness detection scheme of face recognition has been suggested, so that, fraudulent photographic images cannot be used (Jee *et al.*, 2006).

For the first time, Ratha *et al.* (2006, 2007) stated the concept of cancelable biometrics using fingerprint templates. The original fingerprint information is transformed to a new template of a certain domain. Because the template does not contain the original information itself, it can be cancelled and reconstructed and the transform parameters changed. The 'one-way function' is used for this transformation. Once it has been transformed, it cannot be restored to the original template. Jeong *et al.* (2006) and Paul and Gavrilova. (2012) suggested the use of cancellable biometrics for face recognition.

Literature review: It has been shown that fixed-length bit-strings can be used in biometric cryptosystems and that they allow fast matching due to bitwise operations. They are also useful for multibiometric feature-level fusion (Gyaourova and Ross, 2012) and biometric key generation schemes (Kelkboom *et al.*, 2010; Sheng *et al.*, 2015). The fixed-length bit-strings representation in biometrics was suggested for fingerprint authentication by Jin *et al.* (2016) who proposed a generic framework to extract fixed-length bit-strings from fingerprint minutiae.

In the present study, we propose a face-recognition scheme using bit-string representation of facial features. Our scheme can also be used to reconstruct bit-strings if the bit-strings are stolen. We can create a 'standard face' of a group and then extracted bit-string representation by comparing a certain subject with the standard face.

MATERIALS AND METHODS

Our proposed method has two steps: making templates of a standard face; extracting bit-strings. If a person must be verified, our system tests if his/her face is similar to the enrolled standard template. After he/she has passed the test, our system compares his/her enrolled standard template to the group's standard template stored in the database previously. By comparing two standard templates, our method makes a fixed-length bit-string representation for that person. Figure 1 shows the overall process of the proposed method. We will explain also why our system is cancellable.

Standard face template: We make two types of standard-face templates. One is for the person and the other is for the group. From geometric facial features, we can select 71 interesting points. We measure all distances

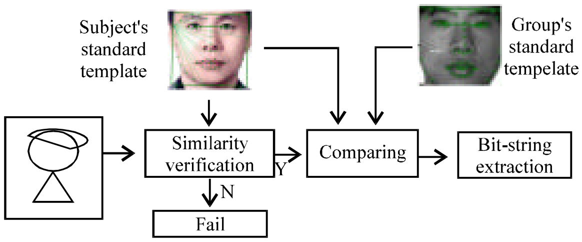

Fig. 1: Proposed method

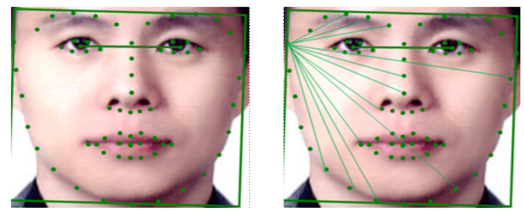

Fig. 2: Points of a face and distances between these points

across from point to point. The total number of distances is 2.485: (71×71 -71)/2 = 2.485. Hence, we can take 2.845 pieces of information of each face. The eyes show almost no change in geometric position due to facial expressions (e.g., a smiley face), so, the distance from right eye centre to left eye centre is used as the transformation reference value for the other distance. Actually, the distance of right eye centre to left eye centre is ˜50 pixels. Hence, we transform the distance between the eyes to 50 and change all distances according to its transformed ratio. We select several facial images of one person, make his/her standard face template from the images and enrol the template in the database. That template will be used when measuring similarity for verification.

Next, we make the standard face template for the group. We choose one face among people from the group and make a set of 2.485 distances as the comparative standard from the face image. Figure 2 shows 71 points of a face and the distances between points.

Bit string extraction: After verification, we compare the person's standard face template to the standard face template of the group. If the distance of the same position between the person's standard face and the standard face of the group is identical, it is bit '1', otherwise it is bit '0'. We compare the two distances within the error correction value.

The total number of distances is 2.485, so, we can extract a maximum of 2.485 bit strings as the face representation. In our experiment, we obtained >500 bit-strings regardless of error correction values. Even by increasing error correction values, we could not derive more bit-strings. Figure 3b shows the length of bit-string representation according to the error correction values from our experiment.

Cancellable bit string representation: While extracting bit string representation, we had two opportunities to transform the biometric data of the original subject. One is the standard face template of the person (which is enrolled in the database) and the other is the standard face template of the group (which is stored in the database). If someone's bit string is stolen, his/her bit-string can be reconstructed by changing one of two standard templates. Due to the size of the group, our proposed system can have more than two standard templates with hierarchical topology. Hence, there are more opportunities to renew the exposed bit string representations. Our binary domain size becomes larger according to the number of the standard templates 'N'; | Domain| = $2{,}485^{N}$.

RESULTS AND DISCUSSION

For our experiment we used Neurotechnology Biometric SDK VeriLook 10.0 (www. neurotechnology.com) and the Yale Face database (http://vision.ucsd.edu/). The latter has 15 individuals and 11 images per individual. These 11 images consist of 'normal', 'centre-right', 'right-right', 'lef-right', 'glasses', 'non-glasses', 'happy', 'sad', 'sleepy', 'surprised' and 'wink'. We tested all 165 face images.

We made the person's standard face by mixing the normal face and centre-right face from each person. All 15 standard templates of the person were stored in the database. We also made the standard template for the group by transforming person number 5 slightly. We considered the least variation when each person's standard template was made and the largest variation when the standard template of the group was selected. We maximised bits for measuring similarity for verification and increased the length of bits for extracting bit-string representation from each person.

Table 1 shows the number of bits which were '1' according to error correction values. Here, bit '1' denotes match correctly between the face image of a subject and the standard template of the subject. Subject 01/02 refers to comparison of the images of subject 02 with the standard template of subject 01. If the error correction is 5 then subject 01 had 41.8% as the similarity for verification; 1,039/2.485×100 = 41.8. Also, subject 02 had 34.9% as the similarity for verification; 868/2.485×100 = 34.9. However, if subject 02 was compared with subject 01, the similarity for verification was only 25.9%. Hence, we showed that the similarity between the face images of the same subject was ˜10% higher than the similarity between other subjects. Figure 3a shows the average bits of matching for

Table 1: Number of bits that were '1'

Error correction values	Subject 1	Subject 2	Subject 1/2
1	29	46	26
2	172	172	133
3	386	352	285
4	703	626	453
5	1039	868	646
6	1332	1086	836
7	1584	1321	1004
8	1800	1561	1187
9	1979	1800	1366
10	2100	1970	1531

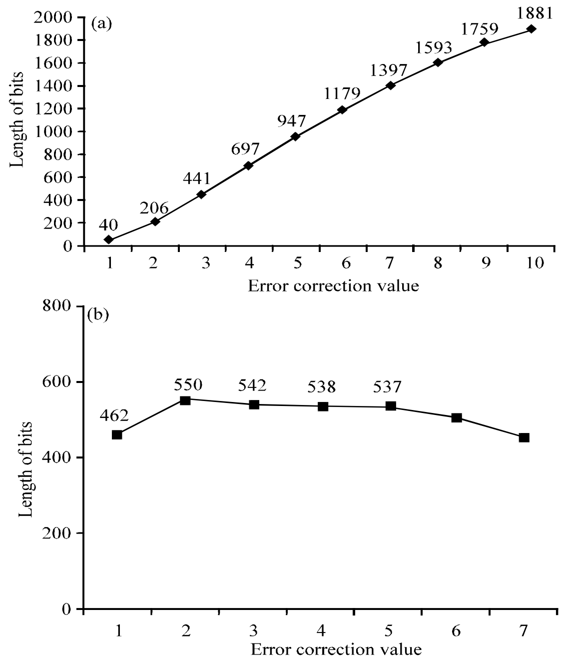

Fig. 3: Length of bits according to error correction values

verification and Fig. 3b shows finally that with error correction value was 4. Hence, we could obtain 550 bit-string representation from 15 subjects. We also verified that those bits were unique among these 15 subjects.

CONCLUSION

We proposed a face-recognition system based on fixed-length bit string representation of facial features.We extracted >500 bit-strings and verified that those bit strings were unique among the faces of 15 subjects. Our proposed system could reconstruct templates by changing one of two standard templates.

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