A BIOMETRIC IDENTIFICATION SYSTEM BASED ON THE FUSION OF HAND AND PALM FEATURES

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ABSTRACT

This paper describes the design and development of a prototype system for the automatic identification of an individual based on the fusion of palm and hand geometry features. Information fusion at the feature extraction and at the confidence level, where the matching scores reported by three matchers are combined, is discussed. After training with the template files of 50 persons, the system was tested with the template files of 61 persons not "seen" during the training phase. The test performance, FAR = 0.0 % and FRR = 1.7 %, suggests that the system can be used in medium/high security Internet environments.

1. INTRODUCTION

Most Internet security services such as confidentiality, authentication, integrity and non-repudiation rely on public-key cryptography as well as on user-identification techniques. Traditional user-identification techniques based on passwords, personal identification numbers (PINs), card keys, etc., cannot differentiate between an authorized person and a fraudulent impostor [1]. Biometrics is an emerging technology [2] that identifies users by their physical and/or behavioral characteristics, and inherently requires that the user to be identified is physically present at the point of identification. The physical characteristics of an individual that are most often used in identification/verification systems based on biometrics are as follows: fingerprint, hand geometry [4], [6], face [5], [6], palmprint [7], iris [8], [9], retina [10], signature [10], voice [11], and lip movement [1]. However, a single physical characteristic of an individual sometimes fails to be sufficient for an identification, for this reason multimodal biometric systems, which integrate two or more different biometric characteristics (e.g., a face, a fingerprint and hand geometry [3], or a face, voice and a lip movement [1]), are being developed to provide a more secure identification/verification system to identify individuals.

This paper describes the prototype of a biometric identification system based on a fusion of palm and hand geometry features. There are some bibliographic references relating to hand biometrics [12], [13], [14], as well as references about commercial systems that are available [15], [16]. There are also references to palmprint verification [7], [17], [18], but, as far as we know, there are no references about systems based on the fusion of palm and hand geometry features. The proposed system uses two levels of fusion: fusion at the feature extraction level (a single sensor for extracting the features of palm and hand geometry) and fusion at the abstract level, where the accept/reject decision is based on a combination of three transition functions and three heuristic rules.

The paper is organized as follows: Section 2 presents the palm and hand geometry feature extraction process, including a description of the image-capture process and preprocessing. Section 3 describes the procedure for an individual identification. The experimental results are presented in Section 4. Conclusions and future research directions are given in Section 5.

2. FEATURE EXTRACTION

2.1 Image capture and database

The palm is the inner surface of the hand between the wrist and the fingers. The hand geometry and the palm features are extracted from the image of the right hand, which is placed on the flat glass surface of a scanner. The user has to put his hand on the scanner with the fingers spread naturally. There are no pegs, which usually serve as control points for the appropriate placement of a hand, and so translation and rotation of the hand (about $\pm 27^{0}$, related to the vertical line of symmetry of the working surface of the scanner) are allowed. The spatial resolution of the images is 180 dots per inch (dpi) / 256 gray levels. Figure 1a. shows a typical image obtained by the scanner. For research and experimental purposes a database composed of five images taken by a scanner, five images captured by a CCD camera placed above the hand, and five images of a lateral view of the hand (obtained by placing a mirror on the right-hand side of the platform) of 111 individuals was collected.

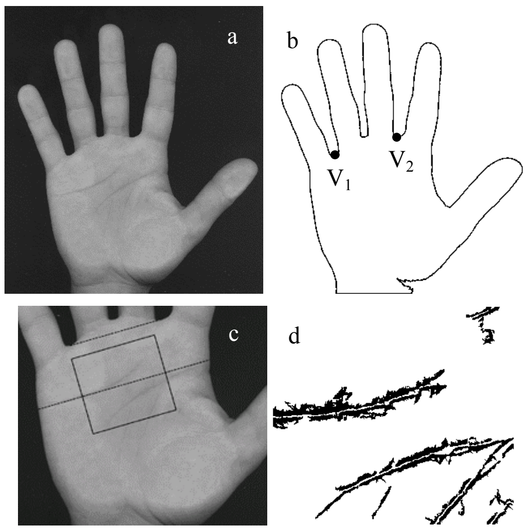

Figure 1: a) Typical image obtained by a scanner, b) Contour of the hand, c) Focus of the attention region (FOAR), d) Processed FOAR

2.2 Preprocessing and feature extraction

The features used in the proposed system are obtained by fusion [3] of the hand geometry and the palmprint characteristics. The hand geometry features are the lengths and widths of the four fingers measured at different heights, as well as width of the hand and distances among valleys between fingers. The palmprint features are based on the principal lines (the heart line, the head line, the life line) (Figure 2) and on texture attributes of the palmprint. Both types of features are invariant to rotation and translation of the hand.

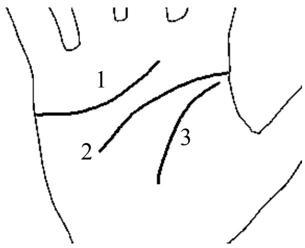

Figure 2: Principal lines of plamprint:
1 heart line,
2 head line,
3 life line

Preprocessing precedes the feature extraction process. The global thresholding is applied to extract the hand from the background. We have experimented using methods based on local thresholding and edge-detection procedures, but due to the regular and controllable conditions of image capturing, simple global thresholding provides satisfactory results. To extract the contour of the hand, a slightly modified contour-tracing algorithm was used [19]. The extracted contour of a hand can be seen in Figure 1b. Based on the contour of the hand the fingertips and the valleys between two fingers were determined. Two reference points were selected on the contour:

i) the valley between the little finger and the ring finger /point V_1/,
ii) the valley between the index finger and the middle finger /point V_2/.

Point V_1 was used to determine a subregion (120 x 60 pixels) of the palm where a segment of the heart line can be detected. On the subregion, the Gaussian mask (9 x 9 pixels, $\sigma^2 = 3.0$) was applied first, and this was followed by the Sobel operator. After a double thresholding the horizontal projection was used to detect the segment of the heart line. The middle point of the segment of the heart line and a joint line connecting the reference points V_1 and V_2 were used to define the focus-of-attention region (FOAR) of the palm (Figure 1c), as well as the three simple hand geometry features (Figure 3b). The 315 x 285 pixels FOAR was preprocessed (Figure 1d) using a Gaussian mask and a modified Sobel operator followed by a double thresholding. In order to detect the principal lines we also experimented with a ridge-line following algorithm [20], but we were not able to obtain satisfactory results. Finally, we formed the composed 422-component feature vector (a sample), where the first 20 components (denoted by $\mathbf{F_x}$) are features containing characteristics of fingers (Figure 3a), 3 components (denoted by $\mathbf{SG_x}$) carry information about the simple hand geometry characteristics (Figure 3b), and 399 components (denoted by $\mathbf{P_x}$) rely on the palm characteristics.

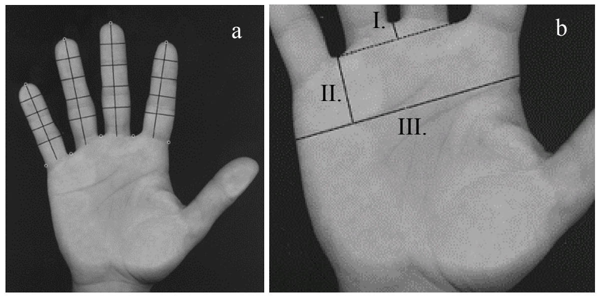

Figure 3: a) Finger features,
b) Simple hand geometry features

3. IDENTIFICATION

3.1 Enrollment

In the enrollment process the feature vectors (the samples representing the user's hand) were saved to the template file. This file also contains pertinent authentication information: in our case each authorized user is represented by a class index. In the enrollment process three samples for each user were taken. On the basis of these samples the additional four samples were generated. So, for each person the template file contains seven samples: three original samples, one average and three samples calculated as an average of each pair of the original samples.

3.2 Identification

Identification is a one-to-many process that compares the biometric information presented by an individual with all the biometric information stored in a database, and decides whether a match can be declared [21]. Figure 4 depicts the data-flow diagram of the identification process applied in the system. During the identification stage the sensor captures the characteristics of the individual to be identified and converts them into the same format as the users' templates. The sample is represented by a feature vector $\mathbf{X}$, which is divided into three subvectors: $\mathbf{F_x}$, $\mathbf{SG_x}$ and $\mathbf{P_x}$. The Euclidean distance d between each subvector and the corresponding subvector of all the feature vectors $\mathbf{N_{ij}} = [\mathbf{F_{ij}}, \mathbf{SG_{ij}}, \mathbf{P_{ij}}]$ in the database was calculated: $d(\mathbf{F_x}, \mathbf{F_{ij}})$, $d(\mathbf{SG_x}, \mathbf{SG_{ij}})$ and $d(\mathbf{P_x}, \mathbf{P_{ij}})$. The index i; $i = 1, 2, 3, ..., u$ denotes a class index of the authorized user (u is a total number of authorized users in the database). The second index $j = 1, 2, \ldots, p$ denotes the j-th sample of the same user obtained during the enrollment process. The distances were transformed into the similarity measures S^F_{ij}, S^{SG}_{ij}, and S^P_{ij} by means of three transition functions, the forms of which were determined during the training phase of the system. In the training phase a database consisting of 50 persons was used in exhaustive testing in order to find the transition functions. The Euclidian distance between the corresponding subvectors of the samples from the same template file was calculated and the number of occurrences of each distance was recorded. The above process was repeated for all the template files in the database. The accumulated results are shown in the histograms (Figures 5a, 5b and 5c). A right downward slope of each histogram was approximated by an exponential function, which was used for calculating the similarity measure.

The fusion at the classification level was performed by means of three heuristic rules and by the total similarity measure TSM_{ij}. The total similarity measure is a combination of three similarity measures:

$$TSM_{ij} = w_1 S^F_{ij} + w_2 S^{SG}_{ij} + w_3 S^P_{ij},$$

where w_1, w_2, and w_3 are weights obtained by experience (during the training phase) / $w_1 = 1.0$, $w_2 = 0.1$ and $w_3 = 0.8$ /.
In the identification process the feature vector **X** is compared with all the samples in the database; this means that u∗p comparisons are needed. Based on the total similarity measure, the three most similar samples $\mathbf{N_{qk}}$, $\mathbf{N_{rl}}$, $\mathbf{N_{sm}}$ from the database are selected as inputs into the final decision process.

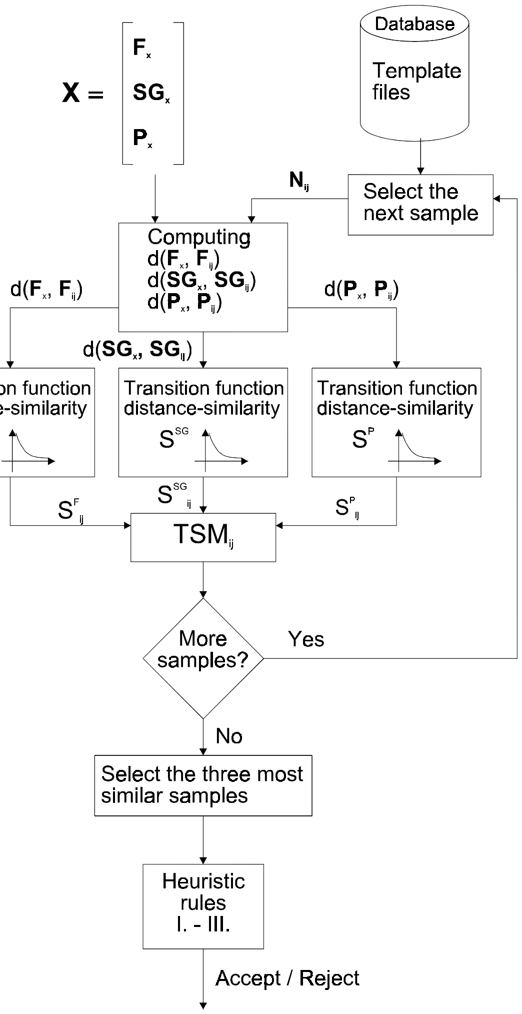

Figure 4: Data-flow diagram of identification process

The final decision as to whether **X** is matched with the sample in the database is based on the following heuristic rules:
I. RULE: All three class indexes of the selected samples have to be the same q = r = s. (In terms of the pattern-recognition problem the 3-NN algorithm must give three patterns from the same class).
II. RULE: $S^F_{qk} > \theta_1$, and $S^F_{rl} > \theta_1$, and $S^F_{sm} > \theta_1$ and
$S^{SG}_{qk} > \theta_2$, and $S^{SG}_{rl} > \theta_2$, and $S^{SG}_{sm} > \theta_2$ and
$S^P_{qk} > \theta_3$, and $S^P_{rl} > \theta_3$, and $S^P_{sm} > \theta_3$.
III. RULE: $TSM_{qk} > \theta_4$ and $TSM_{rl} > \theta_4$ and $TSM_{sm} > \theta_4$ and
$(1/3)\ (TSM_{qk} + TSM_{rl} + TSM_{sm}) > \theta_5$.

The threshold values θ_i; i = 1, 2, …, 5 were determined experimentally during the training phase using the database consisting of 50 individuals.

If all three rules are satisfied, then the individual represented by **X** is successfully identified as a user registered in the database with a class index (see I. RULE).

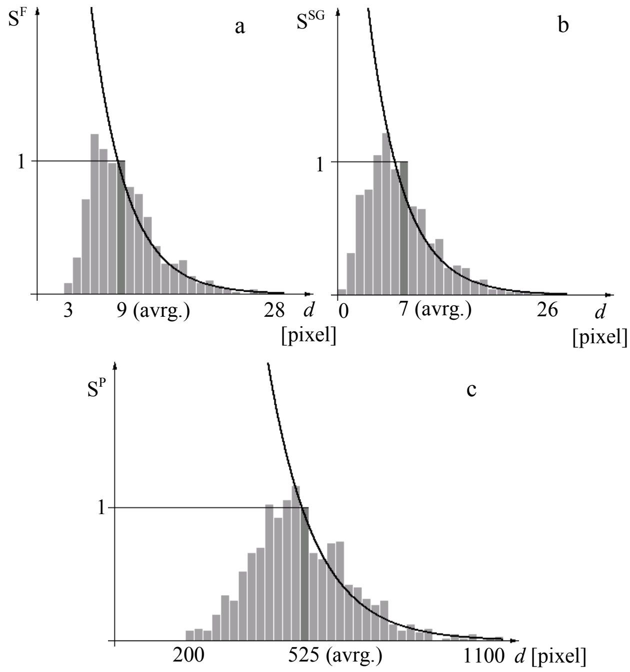

Figure 5: Transition functions for
a) fingers: $d(\mathbf{F_x}, \mathbf{F_{ij}}) \rightarrow S^F_{ij}$
b) simple hand geometry: $d(\mathbf{SG_x}, \mathbf{SG_{ij}}) \rightarrow S^{SG}_{ij}$
c) palm: $d(\mathbf{P_x}, \mathbf{P_{ij}}) \rightarrow S^P_{ij}$

4. EXPERIMENTAL RESULTS

The biometric identification system was tested using a database of 61 persons who were not used in the training phase. Five images of each person's hand were captured, thus a total of 305 images were made available. In the enrollment phase we used three images, and so for testing the users there were two available images. However, for the impostors all five images were available for testing.
The experiment proceeded as follows (Figure 6): One template file was randomly selected from the set of 61 template files, as input in the enrollment process. The remaining 60 files were considered as impostors' template files. The identification was performed and the results were recorded. After this, from 60 template files, another file is randomly selected and added to the set of template files of authorized users. So we got two user template files and 59 impostor files. Again, a process of identification was performed and the results were recorded. The above procedure was repeated until the 60 user template files and 1 file of an impostor were obtained. The whole of the above-described process was repeated 20 times. There was a total 12810*x*20 matching between samples during the experiment.
The described experiment gave the following results for the identification: the false-acceptance rate (FAR) was 0.0 % and the false-rejection rate (FRR) was 1.7 %. We were also interested to find a way in which the fusion at the feature extraction and accept/reject decision levels has an influence on the results of the identification. Table 1. shows the FAR and FRR using the fusion of the different features. For example, if only finger features are used for the identification, we have

obtained the slightly unexpected results: FAR = 0.0 % (!) and FRR = 5.2 %. In the case of using only palm features FAR was 8.1 % and FRR was 6.1 %. A fusion of simple geometry and palm features (SG-P) improves the results (FAR = 2.6 % and FRR = 2.3%) (Table 1.).

	F	SG	P	F-SG	SG-P	F-P	F-SG-P
FAR [%]	0	32.6	8.1	0	2.6	0	0
FRR [%]	5.2	27.7	6.1	4.6	2.3	1.8	1.7

Table 1: The FAR and FRR using F - finger features, SG - simple geometry features, P - palm features, and fusion of these features (e.g. F-P denotes fusion of finger (F) and palm (P) features)

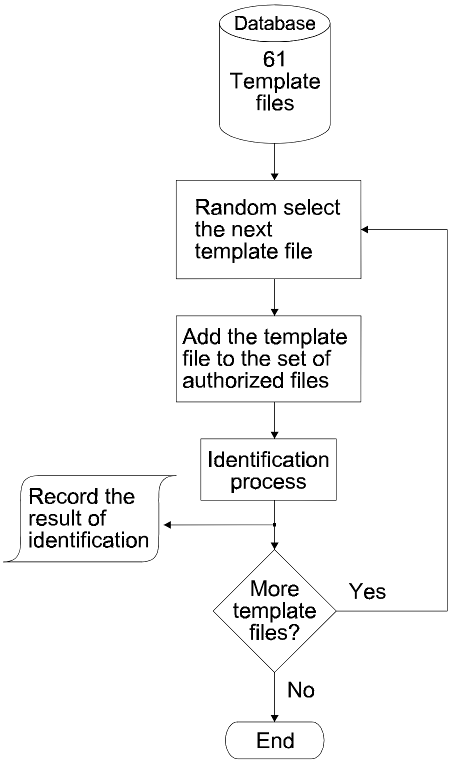

Figure 6: Data-flow diagram of experimental testing of the system

5. CONCLUSION

We have designed a prototype biometric identification system based on the fusion of hand geometry and palm features. We have presented the initial results of the identification based on biometric measurements of 111 individuals. A database of 50 persons was used in the training phase of the system, and additional template files of 61 persons were used for testing the system. The experimental results showed that information fusion at the feature extraction level and at the confidence level (where the matching scores reported by three matchers are combined) improves the results of the identification. The results, FAR = 0.0 % and FRR = 1.7 %, have demonstrated the possibility of using this system in medium/high security environments (Web access, e-commerce).
Further work should be undertaken to increase the database size with template files collected over a longer period of time, as well as experimenting with novel palm characteristics like datum points and global texture features.

6. REFERENCES

1. R. W. Frischholz, U. Dieckmann, "BioID: A Multimodal Biometric Identification System", IEEE Computer, Vol. 33, No. 2, February 2000, pp.64-68.
2. Proceedings of the IEEE, Vol. 85, No. 9, September 1997, Special Issue on Automated Biometric Systems.
3. A. Ross, A. Jain, J-Z. Qian, "Information fusion in Biometrics", rossarun.jain.cse.msu.edu, 2001, 6 pages.
4. A. K. Jain et al., "As Identity-Authentication System Using Fingerprints", in [2], pp. 1365-1388.
5. J. Zhang, Y. Yan, M. Lades, "Face Recognition: Eigenface, Elastic Matching, and Neural Nets", ibid, pp.1423-1435.
6. L. C. Jain et al., (eds), "Intelligent Biometric Techniques in Fingerprint and Face Recognition", CRC Press, 1999.
7. W. Shu, D. Zhang, Automated Personal Identification by Palmprint", Opt.Eng. 37(8), August 1998, pp.2359-2362.
8. R. P. Wildes, "Iris Recognition: An Emerging Biometric Technology", in [2], pp.1348-1363.
9. M. Negin et al., "An Iris Biometric System for Public and Personal Use", IEEE Computer, Vol. 33, No. 2, February 2000, pp.70-75.
10. S. Pankanti, R. M. Bolle, A. Jain, "Biometrics: The Future of Identification", ibid, pp.46-49.
11. J. P. Campbell, "Speaker Recognition: A Tutorial", in [2], pp.1437-1462.
12. R. Sanchez-Reillo, C. Sanchez-Avila, A. Gonzalez-Marcos, "Biometric Identification Through Hand Geometry Measurements", IEEE Tran. On the PAMI, Vol. 22, No. 10, October 2000, pp. 1168-1171.
13. A. K. Jain, A. Ross, S. Pankanti, "A Prototype Hand Geometry-based Verification System", Progress Report, IBM Contract No. 444004069, 1999.
14. Biometric System, Cesena, 1998, http: //www.csr.unibo.it
15. Recognition Systems Inc, http://www.recogsys.com
16. B. Spencer, "Biometrics in Physical Access Control Issues, Status and Trends", http://www.recogsys.com
17. D. Zhang, W. Shu, "Two Novel Characteristics in Palmprint Verification: Datum Point Invariance and Line Feature Matching", Pattern Recognition 32, 1999, pp.691-702.
18. J. You, W. li, D. Zhang, "Hierarchical Palmprint Identification via Multiple Feature Extraction", Pattern Recognition 35, 2002, pp.847-859.
19. T. Pavlidis, "Algorithms for Graphics and Image Processing", Springer Verlag, Berlin, 1982.
20. D. Maio, D. Maltoni, "Minutiae Extraction and Filtering from Gray-Scale Images", in [6], pp.155-192.
21. W. Shen, M. Surette, R. Khauna, "Evaluation of Automated Biometrics-Based Identification and Verification Systems", in [2], pp.1464-1478.