Sánchez-Reíllo R. (2009) Hand Geometry. In: Li S.Z., Jain A., (eds.) *Encyclopedia of Biometrics*. Springer, Boston, MA.

DOI: https://doi.org/10.1007/978-0-387-73003-5_251

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Hand Geometry

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Synonyms

Hand biometrics; Hand shape biometrics

Definition

Biometric modality based on identifying a person by the shape of his or her hand. In its basic form, it is based on taking a photograph of the user's hand while placed on a surface, and after a ▶ contour detection, finding singular points and taking measurements among them.

Introduction

Hand Geometry is considered as a medium-profile biometric modality which reaches a really high level of user acceptance with low computational cost. Not being one of the first biometric modalities, it has gained great popularity due to the success of some commercial products, at the end of the twentieth century. In fact, the commercial product from Schlage Recognition Systems, known as HandKey II [1], was one of the most sold at the beginning of the 2000s, especially for physical access control systems and time and attendance control.

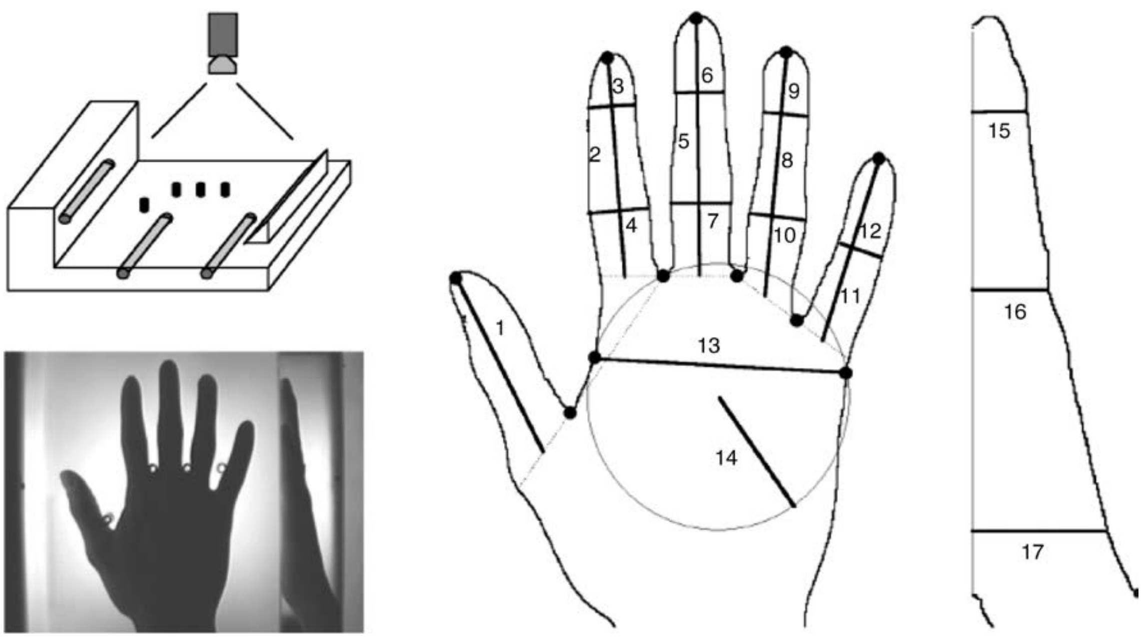
As mentioned below, after some initial works, other scientists have continued researching on other algorithms and more comfortable means of using this technology. Error rates achieved are not as low as those modalities considered as high-performance ones (e.g., fingerprint, iris or vascular). In order to gain applicability, some researchers have included this technology in multimodal biometric systems, reducing error rates, and gaining in ▶ usability and user acceptance.

Basics and Initial Works

Hand Geometry biometrics is based on the measurement of the shape of the contour of the hand [2], including finger widths at several points, finger lengths, palm shape, deviation angles, etc. Main idea comes from the Bertillon system (http://en.wikipedia.org/wiki/Bertillon) used during the late nineteenth century to identify prisoners. But it was not till 1997 that the first paper in a scientific journal is found. In such paper, among may other interesting things, Golfarelli et al. [3] outline a system based on a semi-opaque plastic material with some fixed ▶ pegs to guide positioning of the hand. With a CCD camera located over the hand, and some light located under the surface plate, a high contrast image of the user's hand is obtained. As to acquire also the lateral projection of the hand, the system is replicated on the side, and a 45 mirror is placed to project such image to the same camera. The counterlight image allows a very easy contour detection of the hand, and from there 17 geometrical features are extracted. Figure 2 illustrates image acquisition and feature extraction steps from this work.

In 1999 and in 2000 two papers were published detailing this biometric modality. They were written by Jain et al. [4] and Sanchez-Reillo et al. [5]. In this last work, the device developed is also based on a CCD camera located over the hand of the user. But differently from the Golfarelli approach [3], here the hand is located over an opaque peg-oriented surface painted in blue (see Fig. 3). The reason for the platform to be blue is that the human skin, no matter the race, has a very low portion of blue component. Therefore discarding all blue component in the RGB, allows an easy way to

Hand Geometry. Figure 1 HandKey II device and illustration of its use as a door lock in a physical access control system [1] (Images published under authorization of Schlage Recognition Systems).



Hand Geometry. Figure 2 Illustration of the Hand Recognition system designed by Golfarelly et al., including a sample of the photographs taken and the geometrical measurements extracted. Images taken from [3]. ©IEEE.

eliminate all background information. As in Golfarelli et al. system [3], also a mirror is placed to obtain the lateral view of the hand. In contrast, the illumination demands of this new system were lower, as only the one coming from the camera built-in flash was employed.

From the image sample acquired, as mentioned above, the background surface is removed by eliminating the blue component of the image. In fact, in order to obtain a better output for next stage, the background removal is done by the following formulae (cropping all negative values to 0):

$$I_{BW} = ((I_R + I_G) - I_B) \quad (1)$$

Afterwards, a Sobel edge-detection is performed, obtaining a binary image where only the borders are in black, while the rest of the image is in white. With this

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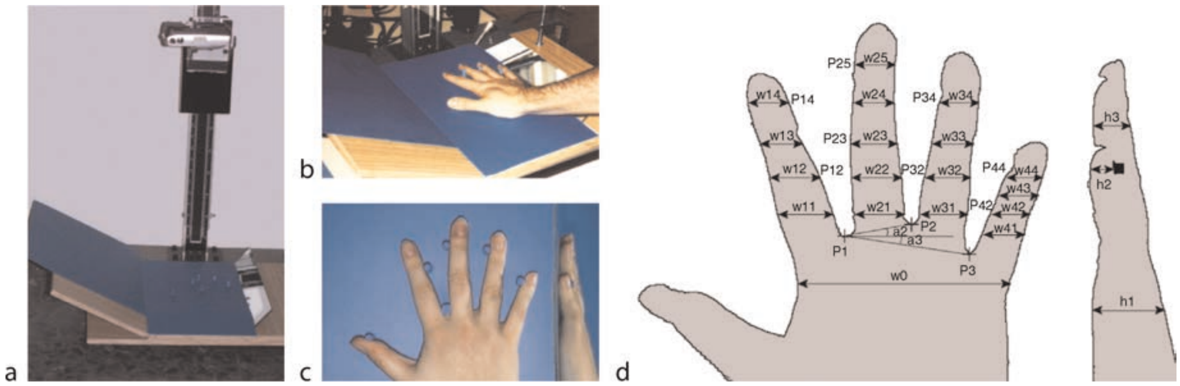

Hand Geometry. Figure 3 Prototype developed in [5] and measurements taken: (**a**) General view of the prototype; (**b**) Positioning of the hand; (**c**) Sample taken; (**d**) Geometric features. Images extracted from [5]. ©IEEE.

result, the way to obtain the 31 absolute features is by locating singular points in the image, and counting pixels among them. In [5], authors proposed the following basic features (as seen in 3d):

- Palm width at a certain point (avoiding conflict with pegs). It is obtained as the number of pixels from the first black pixel on the right side of the top view of the hand, to the next black pixel along the same horizontal line, after going through a set of white pixels moving to the left.
- Finger widths at certain points, also avoiding pegs and ring area, and obtained in an analogue way as mentioned with the palm width.
- Palm and finger heights, through the same mechanism as mentioned above, but this time with the side view of the hand.
- Finger curvature or Deviations. This is defined by the distance between a middle point of the finger and the middle point of the straight line between the inter-finger point and the last height where the finger width is measured. Equation used can be seen below, where exponents refer to the coordinate used, and subindex defines the finger used and the width measurement used.
- Angles between inter-finger points and the horizontal line, which reflects the depth of each of the inter-finger point.

$$deviation = P_{12}^{X} - \frac{P_{14}^{X} - P_{1}^{X}}{P_{14}^{Y} - P_{1}^{Y}}(P_{12}^{Y} - P_{1}^{Y}) \quad (2)$$

From those features, the feature space was grown by adding relative measurements, i.e., relationships among different sets of basic features. Authors, after applying a Principal Component Analysis, discovered that from all those measurements, only 25 features had significant discriminant properties. Figure 3d shows the 25 absolute measurements from whose the final 25 features extracted.

Authors researched the behavior of four different comparators: Euclidean Distance, Hamming Distance in the continuous domain (as seen in the equation here (In $d_{hamming}$ equation: x_i refers to the ith component of the sample, L is the feature vector length, t_i^m is the mean of the ith component, and t_i^v is the standard deviation of the ith component.), Gaussian Mixture Au1
Models (GMM) and Radial Basis Function Neural Networks (RBF-NN). Also they analyzed the dependence of the performance with the number of samples used during enrollment. Results showed that best performance was achieved with GMMs, using five enrollment samples, and that the system did not loose much of the performance is the number of features reduced down to 15 (another relevant work can be seen in [?]). As the number of features is so low and each of Au2
them can even be coded in one single byte, the viability of integrating this modality with smart cards was a reality, and even the development of a match-on-card prototype was shown in [6].

$$d_{hamming}(x_i, t_i^m) = \#\{i \in \{1, \ldots, L\} / |x_i - t_i^m| > t_i^v\} \quad (3)$$

As already mentioned, it is of significant importance to show the success of the first commercial systems, because these systems demonstrated the viability of this biometric modality in real scenarios. The first unit shown was in 1972 from Identimat, but popularity was gained by the products of Recognition Systems. They developed their first prototype named HandKey ID3D before 1990, and improved such system in 1997 by launching HandKey II (shown in Fig. 1). Hundreds of thousand units have been sold, including applications in Universities, Airports, or Nuclear Plants. This technology has gained wide application and acceptance, especially in Access Control Systems, and in Time and Attendance Control.

Evolutions from Initial Works

From the results shown in the previous mentioned works, several R&D groups have worked in this biometric modality. They have improved the system in several ways. One of those working lines has been improving usability by removing the orientation pegs. Some researchers use a commercial scanner (e.g., [7, 8]), while others have worked not only in a peg-free, but Au4 also a contact-free system (e.g., [?, 9, 10]).

Other working lines have been focused in new feature extraction approaches. Some authors have increased the number of features, by including not only geometrical measurements, but also information about the hand contour [11]. Kumar and Zhang [12] improved verification rates in 4–7%, by discretizazing features based on entropy studies. Gross et al. [9] have worked with Active Appearance Models. Others have worked in modeling hand contour and extracting features by curvature gradient (e.g., [13]). Ma et al. model hand geometry by using B-Spline curves [14]. Other authors work with neural networks (e.g., [11]), either for performing the whole identification process, or just for the comparison block.

Most of these studies claim error rates below 5%. Some authors give even better figures, approaching a 99% of identification accuracy. But even though, there are some major open issues regarding this biometric modality. One of those is the size of databases used for testing. Unfortunately in most works such databases are quite small, going up to 100 users with 10 photos per user.

There are still some open issues, especially nowadays and within some kind of population. The expansion in the use of jewelery, such as rings or piercings with a wide variety of shapes and sizes, can be considered as image artifacts by hand recognition systems, and lower the identification rates. Also tattoos, and specially those made in several colors can provoke the denial of use by the hand recognition system. These kind of problems have to be considered by new systems, to gain universality.

Usability and Multimodality

One of the most important facts related to this biometric modality is its great usability. It seems that users do not feel themselves afraid of using the system, neither of noting their privacy attacked. Kukula and Elliott [15] carried on a study that showed that 93% of users enjoyed the system, nearly all found it easy to use, and no one had privacy concerns. Kukula et al. [16] have also studied the effects of training and habituation in using the system, showing a better performance when users are familiar with the identification device.

This great usability, together with the fact that other biometric modalities use the same part of the body (e.g., palmprints or fingerprints), have pushed researchers based on multimodal biometrics to use this biometric modality. Fusion works using palmprints and hand geometry can be found in [17] or [7]. Other authors work even with three modalities, adding fingerprints to the previously mentioned ones, like in [18] or [8]. Or even some authors have developed multimodal prototypes with other non-hand-based modalities [19, 20].

Summary

Hand Geometry is a biometric modality whose promising features are the ease of use and high friendliness to the user. Furthermore, researchers have demonstrated that error rates below 5% are possible, and when applied to limited number of users, the level of performance is high enough for certain applications. Commercial products have found their business applications in Access Control Systems, as well as in Time and Attendance environments.

Related Entries

- ▶ Gaussian Mixture Models
- ▶ Hand Data Interchange Format

▶ Hand Databases and Evaluation
▶ Hand-Geometry Device
▶ Match-on-Card
▶ Multi-Modal Systems
▶ User Acceptance

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