Trends in Hand Geometry Biometrics

Tomislav Fotak, Petra Koruga, Miroslav Bača
Faculty of Organization and Informatics, Centre for biometrics
University of Zagreb
Pavlinska 2, 42000 Varaždin, Croatia
{tomislav.fotak, petra.koruga, miroslav.baca}@foi.hr

Abstract. *Researchers in the field of biometrics found that human hand contains some characteristics that can be used for personal identification. Some of these are hand geometry and hand shape. These biometric characteristics are more than 30 years old and are very popular and widely accepted among people. That makes them suitable for development of various acquisition and authentication methods. So far, many contact-based and contact-less systems have been developed in the academy and commercial sector. Contact-less biometrics is becoming more important in this field, thus making the researchers to concentrate their efforts in this direction.*

Keywords. Hand biometrics, hand geometry, hand shape, contact based biometrics, contact-less biometrics

1 Introduction

Researchers in the field of biometrics found that human hand, especially human palm, contains some characteristics that can be used for personal identification. These characteristics mainly include thickness of the palm area and width, thickness and length of the fingers. Large numbers of commercial systems are using these characteristics in various applications.

Hand geometry biometrics is not a new technique. It is first mentioned in the early 70's of the 20th century and it is older than palm print which is part of dactiloscopy. The first known use was for security checks in *Wall Street*.

Hand geometry is based on the palm and fingers structure, including width of the fingers in different places, length of the fingers, thickness of the palm area, etc. Although these measurements are not very distinctive among people, hand geometry can be very useful for identity verification, i.e. personal authentication. Special task is to combine some non-descriptive characteristics in order to achieve better identification results. This technique is widely accepted and the verification includes simple data processing. Mentioned features make hand geometry ideal candidate for research and development of new acquisition, preprocessing and verification techniques.

This paper is organized as follows: Section 2 presents the brief history of hand geometry biometrics techniques. After that basic hand geometry features are presented in the section 3, followed by the description of the contact based and contactless hand geometry researches in the academic and commercial sector. In the final section we present the idea for the further research of this biometric characteristic and conclude the paper.

2 Brief history of hand geometry biometrics

Anthropologists believe that humans survived and developed to today's state (*Homo sapiens*) thanks to highly developed brains and separated thumbs. Easily moved and elastic human fist enables us catching and throwing various things, but also making and using various kinds of tools in everyday life. Today, human fist is not used just for that purpose, but also as a personal identifier, i.e. it can be used for personal identification. Even old Egyptians used personal characteristics to identify people. Since then technology made a great improvement in the process of recognition and modern scanners based on hand geometry are now using infrared light and microprocessors to achieve the best possible comparison of proposed hand geometry patterns.

During the last century some technologies using hand geometry were developed. They ranged from electromechanical devices to electronic scanners. The history of those devices begins in 1971 when US Patent Office patented device for measuring hand characteristics and capturing some features for comparison and identity verification [5], [11], [18]. Another important event in the hand geometry history was in the mid 80's when Sidlauskas patented device for hand scanning and founded *Recognition Systems Inc. Of Campbell*, California [22]. The absolute peek of this biometric characteristic was in 1996 during the Olympic games in Atlanta when it was used for access control in the Olympic village [24].

Intensive academic research of this subject began in the late 90's. Golfarelli, Maio and Malton addressed the problem of performance evaluation in biometric verification systems [10]. In that research they used prototypes based on hand shape and human face to prove their theory. Jain, Ross and Pankanti [12] developed non-commercial verification system based on hand geometry. Jain continued to work and publish in this field. The result was new paper published in the same year [13]. A year after, in 2000, another important paper was published [21]. That was the first paper that addressed the identification problem based on hand geometry features with very satisfying results (97% identification accuracy).

Formal recognition of this biometric characteristic came in 2004 [14]. Authors evaluated hand geometry as widely acceptable and easy collectable biometric characteristic. Since then, many hand geometry systems were developed. They combine various features (distances, contour, palm print, angles, 2D and 3D features) and recognition methods.

Nowadays, all hand geometry systems can be divided into two categories, according to image acquisition criteria:

- Contact-based hand geometry
- Contact-less hand geometry

While systems in the first category were very popular in the beginning of the hand geometry evolution, last few years there are more systems that are contact-less, trying to improve user acceptability of this biometric characteristic. We will describe these categories later in the paper.

3 Hand geometry features

As we mentioned earlier, hand geometry is widely acceptable and easy collectable biometric characteristic. Varchol and Levicky [25] say that hand geometry is considered to achieve medium security, but with several advantages compared to other techniques:

- medium cost as it only needs a platform and medium resolution reader or camera,
- it uses low-computational cost algorithm, which leads to fast results,
- low template size (from 352 to 1209 bytes), which reduces storage needs,
- very easy and attractive to users – leading to great user acceptance,
- subconscious connection with police, justice and criminal records.

They also emphasize that the availability of low costs, high speed processors and solid state electronics made it possible to produce hand scanners at a cost that made them affordable in the commercial access control market. Also, environmental factors do not appear to have any negative effects on the verification accuracy, but the performance of these systems might be influenced if people wear big rings, have swollen fingers or do not have fingers at all.

Authors of the presented paper referred to contact-based hand geometry systems, but today the costs of this biometric characteristic is even lower than four or five years ago since the development of hand geometry biometrics goes in the direction of the contact-less biometrics and one can make the acquisition using simple web camera or even built-in camera in personal laptops. Nevertheless, professional systems still use very expensive equipment for hand geometry, with a price up to $2000 [23].

Template size up to 1KB significantly reduces storage needs. Systems require almost real-time user authentication. That means that templates should be even less in size than mentioned. Fortunately, this is the case in todays systems. Templates can vary from 9 bytes (two-finger geometry) to 100 bytes and they often do not exceed that size [19]. This way hand geometry device is operating as a stand-alone unit and it allows a large number of templates to be stored in the device's internal memory, processing time is saved and it permits the storage of templates on the identification cards.

That hand geometry devices can operate in harsh environmental conditions and are therefore suitable for indoor as well as outdoor deployment was also mentioned in [4]. They rely on hand shape only and therefore are not dust and scratch sensitive. This feature makes this characteristic suitable for access control in almost every branch, even if the physical labor is involved.

3.1 Global hand geometry features

Jain et al. [12] came to an conclusion that hand geometry features themselves are not very discriminative. This is due to many existing features (about 50). Therefore, they cannot be used for personal identification, but instead can be used for verification. If one wants to build more complex and demanding systems it is recommended to use some other hand features such as hand shape or event palm- and finger-prints.

Despite given constraints for personal identification, researchers in this field are continuing to develop new methods for user authentication. To be able to do that they have to identify some basic hand geometry features. Different set of features were identified for contact based and contact-less hand geometry biometrics. In contact-less field, probably the most complete set of features was described in [2]. Authors defined 30 global features. These features are very exact, but can be represented as global features of contact-less 2D hand geometry. Given features are shown in Fig 1. and enumerated after the figure.

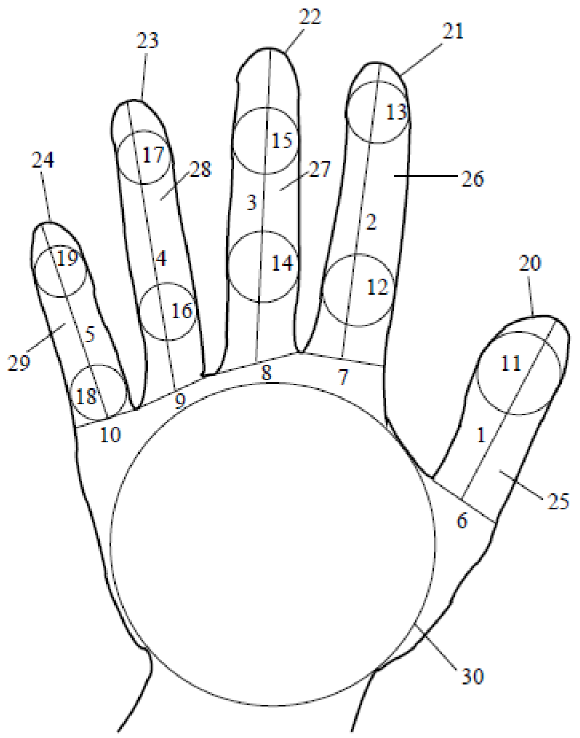

Figure 1. Hand geometry features [2]

Extracted features from Fig 1 are as follows:

1. Thumb length
2. Index finger length
3. Middle finger length
4. Ring finger length
5. Pinkie length
6. Thumb width
7. Index finger width
8. Middle finger width
9. Ring finger width
10. Pinkie width
11. Thumb circle radius
12. Index circle radius lower
13. Index circle radius upper
14. Middle circle radius lower
15. Middle circle radius upper
16. Ring circle radius lower
17. Ring circle radius upper
18. Pinkie circle radius lower
19. Pinkie circle radius upper
20. Thumb perimeter
21. Index finger perimeter
22. Middle finger perimeter
23. Ring finger perimeter
24. Pinkie perimeter
25. Thumb area
26. Index finger area
27. Middle finger area
28. Ring finger area
29. Pinkie area
30. Largest inscribed circle radius

If we are dealing with 3D hand geometry features than we can talk about contact-based hand geometry biometrics. Jain, Ross and Pankanti defined sixteen axes along which feature values are computed. Those features include length and width of the fingers, aspect ratio of the palm or fingers, thickness of the hand, etc. [12]. Defined axes are shown on the Fig 2.

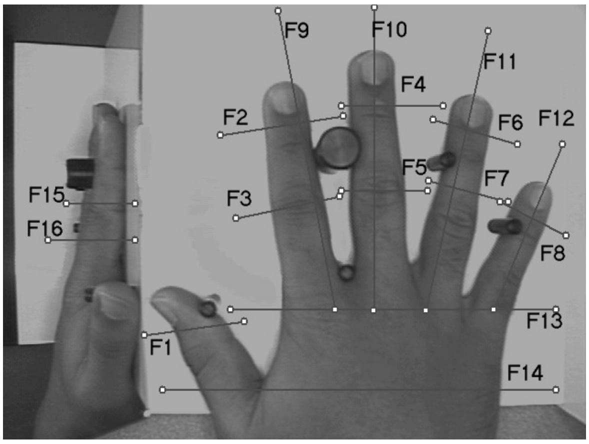

Figure 2. The sixteen axes along which feature values are computed [12]

By combining given 2D and 3D features one can build more complex hand geometry systems. Although, it is still hand geometry only, using three-dimensional space gives us more specific information about human hand. Since 3D features are closely connected with contact-based hand biometrics, we find that the next step in the development of this biometric characteristic would be obtaining 3D features contact-less.

4 Contact-based and contact-less hand geometry biometrics

We already categorized hand geometry systems into two categories: contact-based and contact-less. In this section we will describe some main papers from each of this categories. The description will start with older and still more commercial oriented category: contact-based biometrics.

Biometric systems in hand geometry have evolved from contact-based systems containing pegs to control the placement of user hand to completely contact-less systems where user collaboration is almost not required at all.

4.1 Contact based hand geometry

Hand geometry has been contact-based from its beginnings and still is in almost all commercial systems. Since it has evolved in last 30 years, one can categorize this field as in [3]:

- Constrained and contact-based

- Unconstrained and contact-based

While the first category requires a flat platform and pegs or pins to restrict hand degree of freedom, second one is peg- and pin-free, although still requiring a platform to place a hand (e.g. scanner).

Three works that make basics for the first category are [10], [12], [13] and [21]. In the first one authors used hand shape features and face features to prove their theory. They addressed the problem of performance evaluation in biometric verification systems and tried to formulate optimum Bayesian decision criterion for a verification system assuming the data distributions to be multinormals. Authors in [12] proposed a system shown in Fig 2. The user had to place his/her hand on the flat surface of the device. The five pegs served as control points for appropriate placement of the right hand of the user. For the verification phase they used four distance metrics: absolute, weighted absolute, Euclidean and weighted Euclidean to verify weather the feature vector of a hand matches with the feature vector stored in database. Later that year, Jain and Duta [13] presented a method for personal authentication based on deformable matching of hand shapes. They used the same peg model as presented earlier. For the verification the Mean Alignment Error (MAE) of corresponding points between two aligned hand shapes was used. To obtain verification result MAE must be smaller than defined threshold. The last paper from this category is [21]. Authors also used flat platform with pegs to guide a hand to fixed location. Image of the hand was obtained with CCD color camera. They measured each of four fingers (excluding thumb) in different widths, avoiding the pressure points. The width of the palm was also measured. Beside that, they extracted middle finger height, little finger height and the palm height. Some deviations such as the distance between middle point of the finger and the middle point of the straight line between the interfinger point and the last height where the finger width is measured. They also extracted angles between the interfinger points and the horizontal. With extracted features authors obtained feature vector of the hand. For the comparison phase four different methods were used: Euclidean distance, Hamming distance, Gaussian Mixture Models (GMMs) and Radial Basis Function Neural Networks. The best results were obtained using GMMs.

The second category gives user more freedom in the process of image acquisition. This step is considered as the evolution forward from constrained contact-based systems. Some newer works in this field are [1], [7]. In the [1] authors presented method based on three keys. The system was based on using Natural Reference System (NRS) defined on the hand's layout. Therefore, neither hand-pose nor a pre-fixed position was required in the registration process. Hand features were obtained through the polar representation of the hand's contour. Their system uses both right and left hands which allowed them to consider distance measures for direct and crossed hands. Authors of the second paper [7] used 15 geometric features to analyze the effect of changing the image resolution over biometric system based on hand geometry. The images were diminished from an initial 120dpi up to 24dpi. They used two databases, on acquiring the images of the hand underneath whereas the second database acquires the image over the hand. According to that they used two classifiers: multiclass support vector machine (Multiclass SVM) and neural network with error correction output codes.

A different approach to this problem was presented in [8]. Authors used raw image processing taken form digital scanner to acquire 31 characteristic positions on the hand. For each hand 4 samples were acquired. From that positions they constructed mathematical graph for each characteristic point based on the position in the normalized image. Using Prim algorithm a minimum spanning tree was calculated for each point. The length of each minimum spanning tree was used in the verification process.

As one may notice, there are many different verification approaches in the contact-based hand geometry systems. So far, the GMMs and SVM give the best results but they are far from satisfying for commercial use.

4.2 Contact-less hand geometry

Due to user acceptability, contact-less biometrics is becoming more important. In this approach neither pegs nor platform are required for hand image acquisition. Papers in this field are relatively new according to ones in the contact-based approach. It is for the best to present just new trends in contact-less hand geometry biometrics.

The most used verification methods in this approach are *k – Nearest Neighbor* (*k-NN*) and *SVM*. These methods are also the most competitive in the existing literature.

In last few years, literature on this problem is rapidly increasing. SVM is the most common used verification and idenfitication method. Authors in [15] acquired hand image with static video camera. Using the decision tree they segmented hand and after that measured the local feature points extracted along fingers and wrists. The identification was based on the geometry measurements of a query image against a database of recorded measurements using SVM. Another use of SVM can be found in the [6]. They also presented biometric identification system based on geometrical features of the human hand. The right hand images were acquired using classic web cam. Depending on illumination, binary images were constructed and the geometrical features (30-40 finger widths) were obtained from them. SVM was used as a verifier. Kumar and Zhang used SVM in their hybrid recognition system which uses feature-level fusion of hand shape and palm texture [17]. They extracted features from the single image acquired from digital camera. Their results proved that only a small subset of hand features are necessary in practice for building an accurate model for identification. The comparison and combination of proposed features was evaluated on the diverse classification schemes: naïve Bayes (normal, estimated, multinomial), decision trees (4 5, LMT), k-NN, SVM, and FFN.

A hybrid system fusing the palmprint and hand geometry of a human hand based on morphology was presented in [26]. Authors utilized the image morphology and concept of Voronoi diagram to cut the image of the front of the whole palm apart into several irregular blocks in accordance with the hand geometry. Statistic characteristics of the gray level in the blocks were employed as characteristic values. In the recognition phase SVM was used.

Beside SVM which is the most competitive method in the contact-less hand geometry verification and identification, the literature contains other very promising methods such as neural networks [20], a new feature called 'SurfaceCode' [16] and template distances matching [3].

Mentioned methods are not the only ones but they have the smallest Equal Error Rate ant therefore are the most promising methods for the future development of the contact-less hand geometry biometric systems.

5 Future research and conclusion

We are currently starting a research that will focus on the idea presented in [8]. Graph theory is mathematical discipline that can be very promising in biometric systems. It seems natural to represent hand features as elastic graph, such as in face recognition systems. The presented method is contact-based and the aim of future research is to make it contact-less. We plan to use classic digital camera and built-in web camera in personal laptops in the phase of image acquisition so the system cost will be minimal.

Another approach in our future research will be fusion of the hand geometry features with handwritten signature. Using basic graph theory concepts in the handwritten signature identification gave us promising results in this field as mentioned in [9]. Combining these two characteristics it is possible to develop non-intrusive and widely acceptable multimodal biometric system.

Subject of hand geometry biometrics is very interesting to researchers due to its acceptability among users. From its beginnings almost 40 years ago it has evolved from contact-based to contact-less. Although contact-based systems are still more in use in commercial systems, contact-less systems are becoming more popular. Having in mind health issues, specially in some cultures, it is expected that contact-less hand geometry biometrics will become a future standard. So far, researches made in this field gave promising results in the verification and identification process. Hopefully, researchers will still try to make this biometric characteristic even better than it currently is.

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