HAND GEOMETRY PERSONAL AUTHENTICATION USING MACHINE LEARNING

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ABSTRACT

Personal authentication system based on hand geometry is proposed. We propose to perform identification and verification based on machine learning methods, in particular K-Nearest-Neighbor. Experimental results on verification show advantages of using machine learning over using the distance function

1 INTRODUCTION

This paper present biometric system based on hand geometry. Hand geometry includes measuring parts of hand like length and widths of fingers, width of palm, etc. Hand geometry is a non-invasive biometry, meaning that it is suitable for middle and low security requirements, because it's suitable for verifying someone's identity, but with a big database it cannot identify he's identity. [1]

The papers shows hand based biometry with two different authentication method: (1) based on machine learning, and (2) distance functions. Taking into account definitions form (1) and [2], we propose the following definition: Biometric is a science which includes procedures and technologies for automated person authentication based on physical, behavioral and chemical characteristics. Complete biometric system based on hand geometry is developed so different authentication methods can be properly tested. Biometric system is: "Multiple individual components (such as sensor, matching algorithm, and result display) that combine to make a fully operational system. A biometric system is an automated system capable of:

1. Capturing a biometric sample from an end user
2. Extracting and processing the biometric data from that sample
3. Storing the extracted information in a database
4. Comparing the biometric data with data contained in one or more reference references
5. Deciding how well they match and indicating whether or not an identification or verification of identity has been achieved." [3]

The sensor in the proposed system is standard document scanner. There is an application developed which uses algorithm for extracting features from acquired image of the hand, as well as matching algorithms for making the decisions about authentication.

2 PROPOSED APPROACH

The proposed system takes hand geometry sample using standard document scanner. To enroll a person to the database, 4 samples of hand geometry of that person's right hand must be acquired. This biometric template is stored in to the database together with personal information, like first and last name, including the persons age and sex, for possible future analysis. The hand geometry sample stored in database is a feature vector composed of 48 ordered pairs which give information for location of point on two dimensional plane:

$$F = \{(x_0, y_0), (x_1, y_1), \ldots, (x_{47}, y_{47})\}$$

Locations of these points are extracted using the feature extraction algorithm described in the next section. When person wants to verify its identity, new scanning of the hand is required, so there is a sample of hand geometry which is compared with samples from the database. Verification (where "live" taken samples is compared with samples from database which are assigned to claimed identity) and identification (where all samples from database are taken into account), are performed with two different algorithms described in section 4.

Figure 1*: Biometric system based on hand geometry.*

The complete process is shown with scheme on figure 2. With image acquisition we get hand image as an input. Acquired image is subjected to preprocessing, and then final processing where features are extracted, resulting with feature vector. Feature vector is an input for last step – decision making, which is performed with two alternative methods: distance functions and machine learning. Decision making produces result of verification, i.e. identification of person whose hand image was acquired as an input.

3 FEATURE EXTRACTION

Image of hand can be acquired using different devices. Acquired image is first preprocessed, and then processed with extracted features as a result.

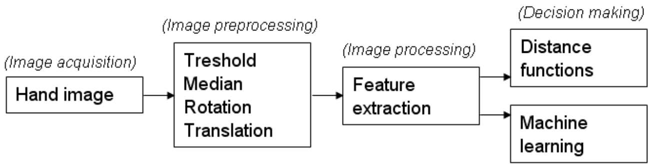

Figure 2*: Schematic view of proposed biometric system.*

3.1 Image acquisition

Methods for image acquisition are differing by type of used device and by required restrictions in placing hand on the device. Most often used devices for prototypes are CCD digital cameras and document scanner. Some systems for image acquisition use pegs for positioning the hand (like the one in [4]), other don't include the pegs for positioning (one of the examples is shown in [5]). The systems without the pegs can be completely unrestricted, allowing user to place the hand in any way on the scanning surface. More often there are some restrictions, like: fingers have to be separated, wrist has to be on the scanning device, and orientation of the placed hand has to be as vertical as possible. Advantage of system with the peg is that after scanning, the location of hand is known what makes the following image processing steps easier. The disadvantages are lower acceptance rate from users (pegs can cause difficulties in placing smaller hands), deformations of hand caused by pegs, the pages have to be removed from the image, the rate of misplaced hands is higher that with systems without pegs [1].
In proposed system image acquisition device is standard document scanner (figure 1). There are no pegs for positioning, but there is a requirement that the fingers are separated while scanning.

3.2 Image preprocessing

Threshold is applied on input image to gain binary silhouette of the hand. Noise is removed from the image with median filter.

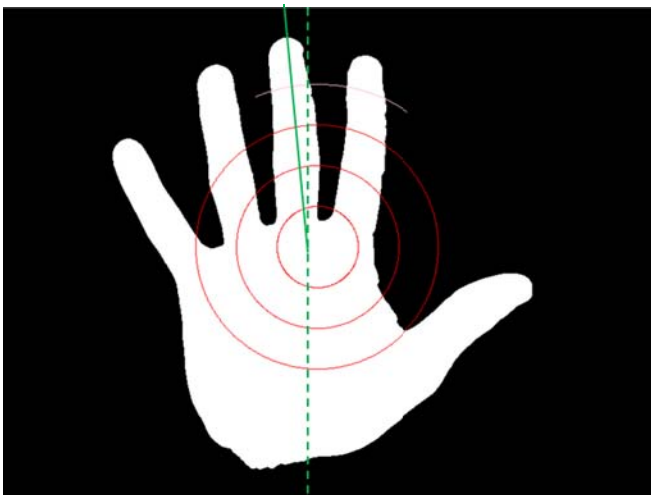

Figure 3*: Rotation of hand silhouette.*

As no pegs where used while acquiring image, we have to identify the location and orientation of the hand. The center of the image, concentric circles are grown until the middle finger and the pointer finger are identified (figure 3). When position of these two fingers is known, the whole hand is rotated so that the orientation of middle finger (which is used as a reference for orientation of whole the hand) is vertical. Using horizontal translation, hand is centered in the middle of the image.

3.3 Points extraction

Preprocessed image and identified locations of points on the edges of middle finger and pointer finger are used to identify all other points of the hand. This is done using basic geometric functions combined with previously know information. Figure 4 shows an example how points on ring finger are identified using previously known points on middle finger.

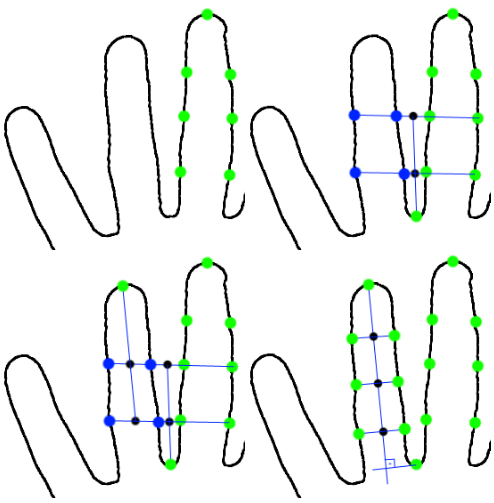

Figure 4: *Extraction of points on edges of ring finger.*

After the points extraction is done there are 48 points identified on the hand. Locations of these points make a feature vector which is stored in the database and used in latter steps for verification and identification.

4 AUTHENTICATION

There are two main categories of personal authentication, these are: identification and verification of person's identity. Identification is problem of establishing an individual's identity, so it answers the question: "Who is he?". Verification is a problem of confirming or denying an individual's claimed identity, so it answers the question: "Is he the one who he claims to be?".

4.1 Machine learning

For each person recorded in the database, we have four hand geometry samples where every sample has 48 points with given information of their location on two dimensional plain. When authentication of a person is performed, the new hand geometry sample is compared to those stored in the database. In the proposed system K-Nearest-Neighbor method is applied. This method is used in the way that for every of the 48 point on the hand, four nearest neighbors are identified (figure 5).

When performing verification the samples from the database are categorized as belonging to claimed identity or not. That means we have only two classes when we do verification. If for some point are among four nearest neighbor more of those belonging to claimed identity, than those which belong to other class (in which are all points belonging to different identity), verification for that person will be successful. Otherwise verification will be unsuccessful.

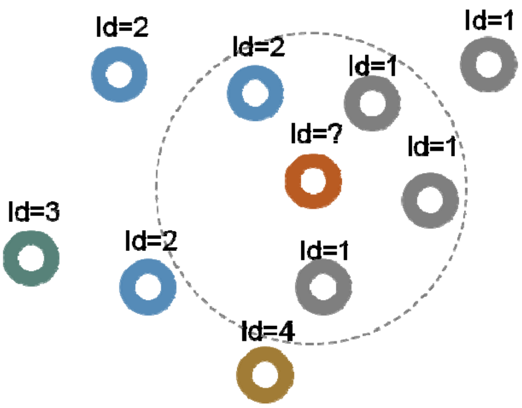

Figure 5*: Identifying 4 nearest neighbors.*

It is noticeable that even when we do verification, we do not perform one-to-one comparison (i.e. we don't compare "live" taken sample with only one sample from database), but make one-to-all comparison like when we perform identification. If we do not make categorization of point into two classes (one for point belonging to claimed identity and for points of all other identities), but keep every identity as a separate class, then with the same amount of work as for verification, we perform identification. For identification we count how many points of every class is among four nearest neighbors and classify the point to the class which has the biggest number of representatives.

Proposed hand geometry template has 48 characteristics, what means that the same K-Nearest-Neighbor method is performed 48 times (once for each position of the hand). Identification is made by number of points classified to each class, so the classification of the whole hand geometry sample is to the class to which the most of its point belong to. Classification of the whole sample can also be made on the "global level". That means that first, for each class is recorded how many points belonging to it, were among four nearest neighbors for any position of the hand. The classification of the sample is then made to the class with biggest number of these. Also, it can be recorded how many times was point of a class first, second third and fourth nearest neighbor, and put a weight making nearer neighbor more important. Method used in testing was "global level" classification without weighting.

4.2 Distance functions

Besides machine learning, distance functions were used for verification. The result of verification using these standard methods can be useful for comparing.

Absolute distance:

$$AD = \sum_{k=0}^{n} |y_i - f_i| \qquad \#$$

Weighted absolute distance:

$$WAD = \sum_{k=0}^{n} \frac{|y_i - f_i|}{\sigma_i} \qquad \#$$

Euclidean distance:

$$ED = \sqrt{\sum_{k=0}^{n} (y_i - f_i)^2} \qquad \#$$

Weighted Euclidean distance:

$$WED = \sqrt{\sum_{k=0}^{n} \frac{(y_i - f_i)^2}{\sigma_i^2}} \qquad \#$$

D1 distance [5]:

$$D1 = \sum_{k=0}^{n} \frac{|y_i - f_i|}{y_i + f_i}$$

5 EXPERIMENTAL RESULTS

The testing was done on a small sample of 10 persons with five images of hand for each, which is good enough only as initial orientation for future work. Results of verification are shown in table 1. Results are shown in CER (central error rate), which show the point where FAR (false acceptance rate) and FRR (false rejection rate) meet.

Method	CER (%)
K-Nearest-Neighbor	2,13
Absolute Distance (AD)	3,33
Weighted absolute distance (WAD)	5,88
Euclidean distance (ED)	5,88
Weighted Euclidean distance (WED)	5,88
D1 distance (D1)	5,88

Table 1: *Results of testing.*

The K-Nearest-Neighbor method outperforms the distance functions. Shown results for K-Nearest-Neighbor method are for identification, which is generalization of verification for this method. Results shown for distance functions are the results of verification.

The performance of K-Nearest-Neighbor method comes with very big cost of time. The algorithm used for verification does not have better complexity than the one used for identification, what is significant disadvantage of this method.

6 DISCUSSION

In this work K-Nearest-Neighbor method is used for verification, i.e. identification. Good performances as well as important disadvantages were identified. This makes good basis for finding a way of increasing the performance of algorithms from aspect of complexity. New and broader testing is required to get more reliable results and to identify the point where hand geometry stops being suitable for identification, as for this biometry is already well determent. As a future work analysis of testing results on particular individual samples could be useful in finding positive effect of merging verification methods. The feature extraction part of the work requires a simulation model to test the performances of this part of a system.

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