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Biometric Human Identification of Hand Geometry Features Using Discrete Wavelet Transform

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1. Introduction

Since the security factor became a basic need for civilization, a lot of systems have been developed. Those systems, try to ensure the safety in all the things that driving a certain degree of exclusivity. Historically, keys, cards and passwords were used as security systems; however, these methods are vulnerable to loss and theft. As a result biometric identification methods emerge in order to tackle the disadvantages of the non biometric classical methods. Biometrics, is an emerging technology that addresses the automated identification of individuals, based on their physiological and behavioral traits. The main advantage of biometric methods is the ability to recognize, which is made by means of a physical feature or a unique pattern (Jain et al. (2008)). With these methods and individual can hardly be victim of plagiarism.

There exist several biometrics cues such as iris (Abhyankara & Schuckersa (2010)), face (Abatea et al. (2007)), fingerprint (Jimenez et al. (2010)), voice (Andicsa et al. (2010)), but one of the cheapest is the hand geometry. Hand geometry, as the name suggests, refers to the geometric structure of the hand (Singh et al. (2009)).

Hand geometry measurement is non intrusive and the verification involves a simple processing of the resulting features. Usually the hand geometry identification involves a digital picture acquisition and translation of the nodal points like: space between fingers, curvature, length and width of the hand into numerical representations used to cross reference with other hand prints stored in a database for a match.

The schemes which uses geometrical features of the hand, focused on characteristics as widths of fingers at articulations, finger and palm lengths, finger deviations and the angles of the inter-finger valleys with respect to the horizontal. The number of features obtained varied in the range of 20-30, and usually the acquisition stage need pegs to define the accurate finger position (Yoruk et al. (2006)).

The ability of associating an identity with an individual is called identification. Hand geometry measurements are easily collectible due to both the dexterity of the hand and due

to a relatively simple method of sensing which does not impose undue requirements on the imaging optics (Zunkel (1998)).

In this paper a method which uses 31 wavelet features for human hand geometry identification is presented. The paper is organized as follows: the related works about hand geometry identification are shown in section 2, the proposed methodology for identification is shown in section 3. Section 4 presents the tests and results obtained. Finally, the conclusions and further works are presented in section 5.

2. Related works

The biometric applied to hand geometry is an important issue which has been part of many investigations over the years, even when the theme is recent compared with other biometric models. There exists evidence to believe that since more than 3200 years ago the geometry of the hand was used to identify humans (Ratha & Govindaraju (1988)).

For example, in the Chauvet cave located in France, the walls were decorated with Palaeolithic art. Around the paintings of the cave there exist palms used to identify the creator of the painting. Additionally, reliable data show that in ancient Babylon and Egypt, the merchants had recognition techniques, by the impressions of the people fingerprint made in clay or by taking the morphology of the palm print.

The commercialization of hand geometry dates to the early 1970s with one of the first deployments at Georgia University in 1974. The US Army began testing hand geometry for use in banking in 1984. These deployments predate the concept of using the geometry of a hand for identification as patented by (Sidlauskas (1988)).

The first commercial device for hand geometry identification was made in 1994 by the Hungarian company Recowere Ltd. The hand identification systems are widely implemented for their ease of use, public acceptance and integration capabilities. In Fig. 1 an image of a commercial scanner is shown.

In the literature there are several works which tackle the problem of hand geometry identification, but never using wavelet features.

The paper of (Singh et al. (2009)) presents an overview of biometric hand geometry recognition. Five different methods were compared and the authors talk about the advantages and disadvantages of each method. An approach that uses the color of the skin of the hand as a feature for recognition is recommended. The best classifier proposed was Gaussian Mixture Models (GMM).

In (Sanchez et al. (2000)) a comparison of four different methods for hand geometry recognition is presented. 31 features were extracted and the classifiers compared were: Euclidean distance, Hamming distance, Gaussian Mixture Models (GMM) and Radial Basis Function Neural Networks. The authors report a 97 percent of recognition success with the method of GMM. The False Rejection Rate (FRR) and False Acceptance Rate (FAR) always remain similar.

A work that uses the coefficients of the Fast Fourier Transform (FFT) and the coefficients of the Discrete Cosine Transform (DCT) as features for hand recognition was presented by (Bolak et al. (2004)). Additionally, a database reduction algorithm is proposed. The classifier used was Euclidean distance and the percentage of recognition using FFT features was 99 and using DCT was 98.



Fig. 1. Example of hand image acquisition device.

The work in (Kumar & Zhang (2007)) presents an algorithm which exploit user-specific dependencies in the feature-level representation. The system employees a discrimination of hand geometry features using entropy-based heuristics. Four classifiers were used: K-Nearest Neighbor (K-NN), Bayes, Support Vector Machine (SVM) and Feedforward Neural Network (FFN). The results demonstrates the improvement of the classifier performance with feature discrimination, and the percent of recognition is equal to 95.

The work proposed by (Polat & Yildirim (2008)) presents a method for hand geometry identification, the system does not required the stages of image preprocessing and feature extraction before the identification. A general regression neural network is used for hand classification. The authors reports an FRR and FAR of 15.

In Table 1 a summary of the related works on hand geometry based is shown, the essential information of the table was collected at (Kanhangad et al. (2009)) and (Lai & Chaw (2009)). The first column, show the authors name and the year of publication, the second, column define the features used and in brackets the method used for classification. The third column, show the overall performance of the system in terms of FAR and FRR. The FAR is the probability of wrongfully accepting and imposter user. The FRR is the probability of wrongfully rejecting a genuine user. Finally, the fourth column show the population size.

3. Proposed methodology

The stages of the methodology for the solution of the problem statement are: a) an image of a hand is acquired, b) the image is preprocessed to enhance it, c) axes reallocation, d) wavelet transform, e) feature extraction in wavelet domain, f) nearest neighbor classification and g) the face of the individual of the hand recognized is displayed. In Fig. 2 an example of the methodology for identification using hand geometry is shown.

3.1 Image acquisition

120 hand images of different individuals were taken using a commercial scanner. The images were taken with a resolution of 300 dpi and the size of each image was 2550 x 3508 pixels as it is shown in Fig. 3.

Authors	Methodology	Performance	Database size
Golfarelli et al. (1997)	17 features including finger lengths (Mean of a multinomial pdf)	FAR = N/A FRR = N/A	100
Jain et al. (1999)	Measurements along 16 different axes (Euclidean distance)	FAR = 2.0% FRR = 15%	50
Jain & Duta (1999)	Alignment of finger shapes and shape distance measurement (match score)	FAR = 2.0% FRR = 3.5%	53
Sanchez et al. (2000)	several width, height and angle measurements (GMM)	FAR = 6.0% FRR = 6.0%	20
Lay (2000)	Distorted pattern of the back of hand (Quadtree)	FAR = 0.0% FRR = 3.9%	100
Kumar et al. (2003)	16 geometry measurements (Normalized correlation)	FAR = 5.3% FRR = 8.2%	100
Bolok et al. (2004)	Coefficients of FFT and DCT (Euclidean distance)	FAR = N/A FRR = N/A	40
Bulatov et al. (2004)	30 features (Training vector bounding box)	FAR = 1.0% FRR = 3.0%	70
Woodard & Flynn (2005)	Shape index (Normalized correlation coefficient)	FAR = 5.5% FRR = 5.5%	177
Xiong et al. (2005)	Elliptical model and finger tip/valley information	FAR = 2.4% FRR = 2.4%	108
Malassiotis et al. (2006)	96 curvature and 3D finger width measurements (L_1)	FAR = 3.6% FRR = 3.6%	73
Kumar & Zhang (2007)	Feature discretization (K-NN, Bayes, SVM, FFN)	FAR = N/A FRR = N/A	100
Polat & Yildirim (2008)	No features (Regression Neural Network)	FAR = 15.0% FRR = 15.0%	140
Adán et al. (2008)	14 Non-landmark features (Time averaged)	FAR = 0.45% FRR = 3.4%	470
Kanhangad et al. (2009)	Fusion of 3D and 2D hand geometry features	FAR = 2.6% FRR = 2.6%	177
This paper	31 Wavelet Features (Nearest Neighbor)	FAR = 11.4% FRR = 10.4%	120

Table 1. Summary of related works on hand geometry based identification

Five different pegs were placed on the scanner (since distances computed on the hand vary substantially with pose and finger configuration), then the user places the hand palm facing downwards, afterwards the hand image is acquired. Especially attention is placed to the localization of the center of the medium finger. The pegs are located symmetrically between the index and ring fingers. Another important point is the position of the thumb finger, because it defines the X axis inside the image, as it is shown in Fig. 4.

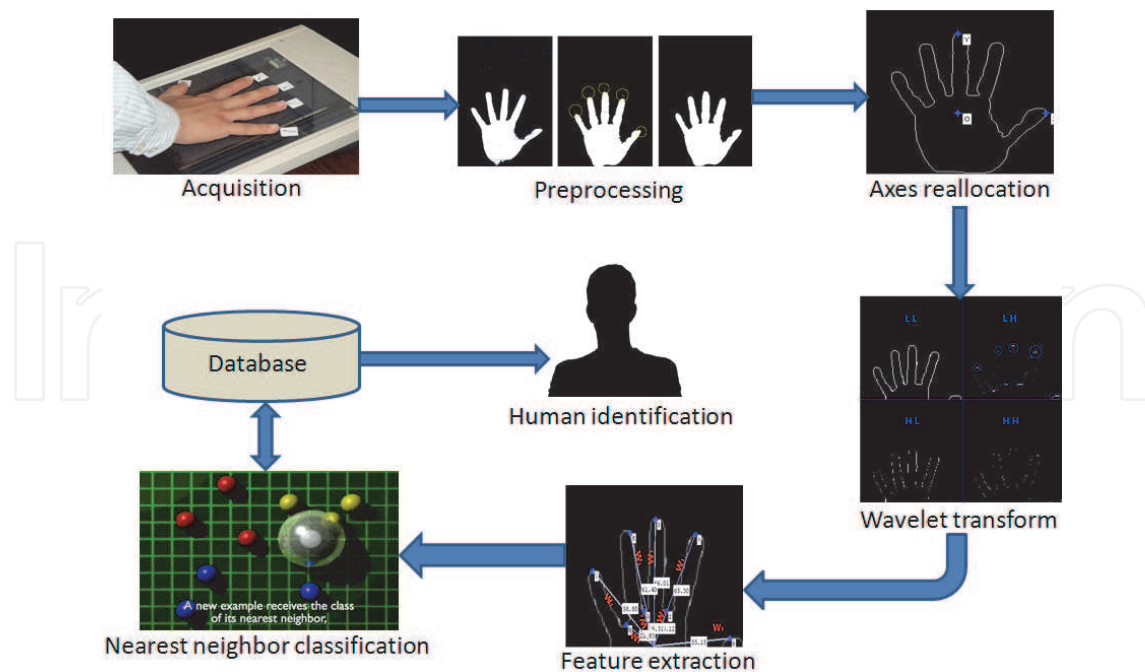


Fig. 2. Scheme of the proposed methodology.



Fig. 3. Example of hand image acquired.

3.2 Preprocessing

The images were obtained in RGB plane, and then changed to grayscale. After that, the Otsu algorithm (Otsu (1979)) was used to compute a threshold in order to binarize the grayscale images. A bidimensional 4×4 median filter is applied to eliminate the salt noise. The next step, is to eliminate the shadows produced by the reflected scanner light against the fingernails. This is made by a morphological operation of erosion for selecting only the big objects inside the binary image (the hand). All the results obtained with image preprocessing are shown in Fig. 5.



Fig. 4. Pegs on the scanner for hand positioning.

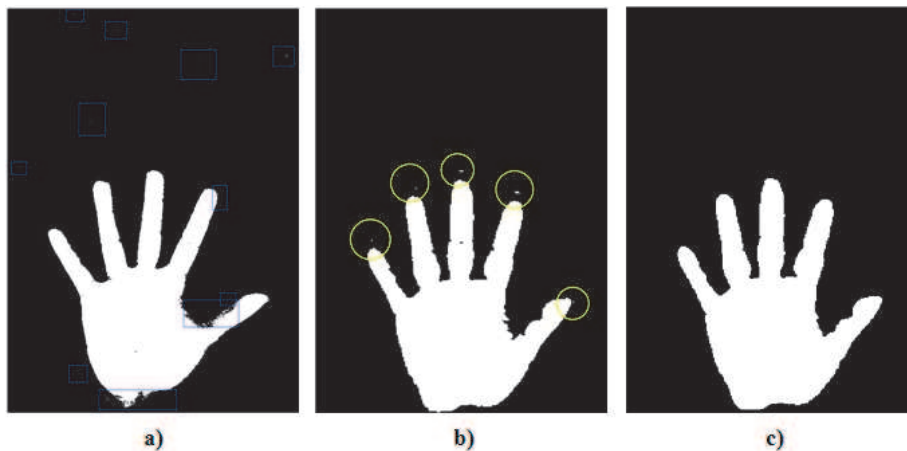


Fig. 5. Hand image preprocessing. a) Binary image, b) Denoised hand and c) Hand after shadow elimination.

3.3 Axes reallocation

After image preprocessing, the natural references of the hand are extracted in order to obtain the X and Y axes using the middle and thumb fingers. The axe Y corresponds to the skeleton of the middle finger, and the axe X corresponds to the straight skeleton of the thumb finger. With the axes located and by deduction a new origin O' is determined.

The translation of the points are computed by an scanning operation. The first pixel of the axes Y is located in order to detect the top of the middle finger. This pixel determine the new position of Y' axe. The same operations is computed to find the position of the thumb finger in X axe. This pixel determine the new position of X' axe.

After image axes reallocation, a Canny filter is implemented in order to obtain only the edges of the hand. The results obtained from axes reallocation and canny edge extraction are shown in Fig. 6.

The image of hand edges is cropped, only those sections defined by the new axes was preserved. The cut is made to avoid recognition mistakes if the people wear a bracelet. After that, all the pixels pertaining to hand contour are extracted and marked in order to obtain a matrix of xy points. The results obtained are shown in Fig. 7.

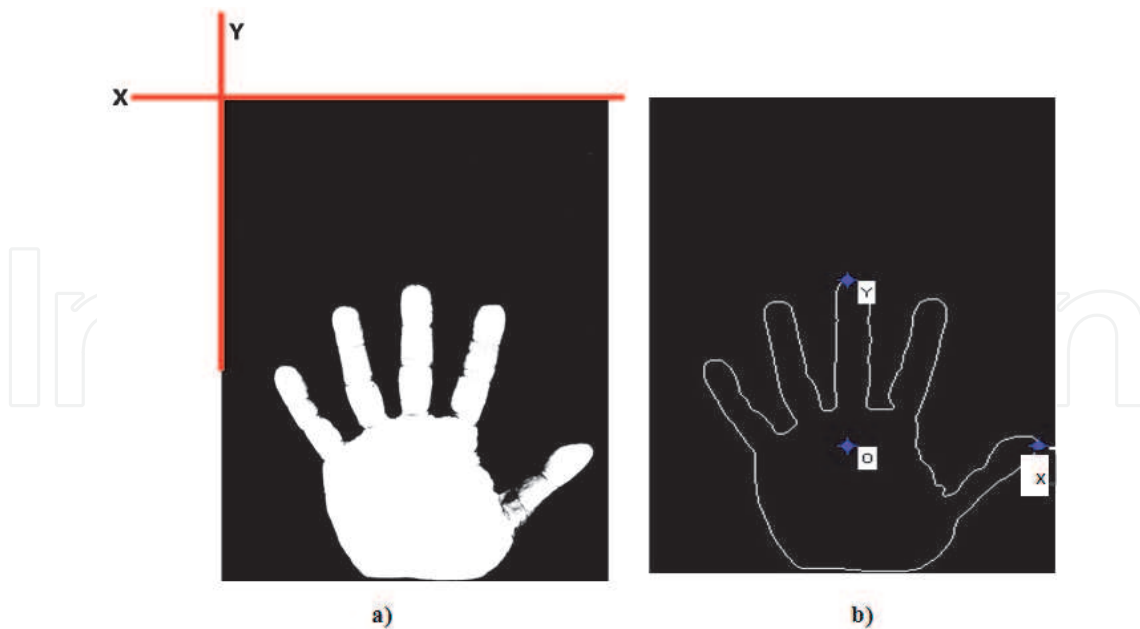


Fig. 6. Axes reallocation. a) Original axes and b) New axes on edge image.

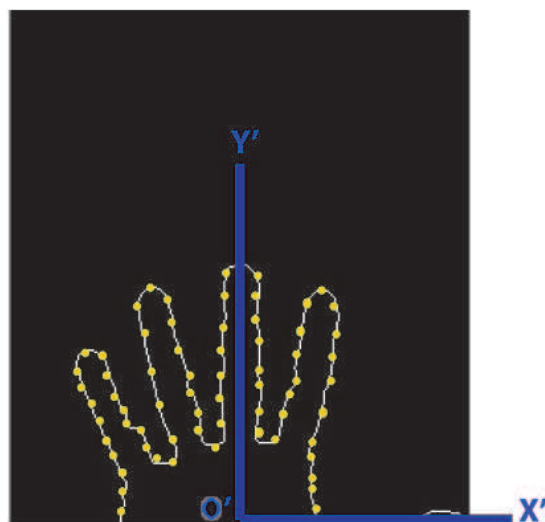


Fig. 7. Image cutting process and positioning of marks on the hand contour.

3.4 The Haar discrete wavelet transform

After axes translation the image is transformed to the wavelet domain. The Discrete Wavelet Transform (DWT) is a tool that can be applied on the discrete data to obtain a multiscale representation of the original data. From the digital point of view, the original information must be represented and delivered in efficient form. The representation efficiency, talks about the ability to capture significant information of an object of interest in a small description. From the practical point of view this representation is obtained by means of structured transformations and fast algorithms (Haar (1910)).

For this paper, the classical one level Haar decomposition is computed. The results obtained after wavelet transform are shown in Fig. 8.

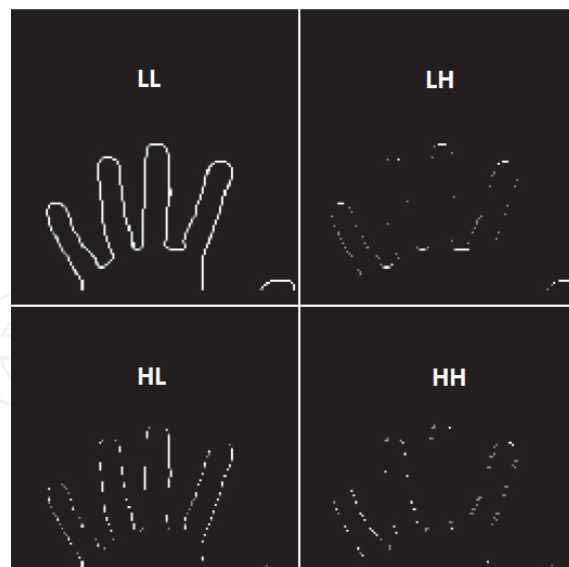


Fig. 8. The hand image transformed to Haar wavelet first level.

3.5 Feature extraction

The horizontal information obtained from *LH* subband is very important, because these horizontal details corresponds to the top points of the fingers and valleys of the hand. An scanning process is made on *LH* subband to detect the coordinates of all these points. An average is performed to select only eight control points defined as P_1 to P_8 as it is shown in Fig. 9.

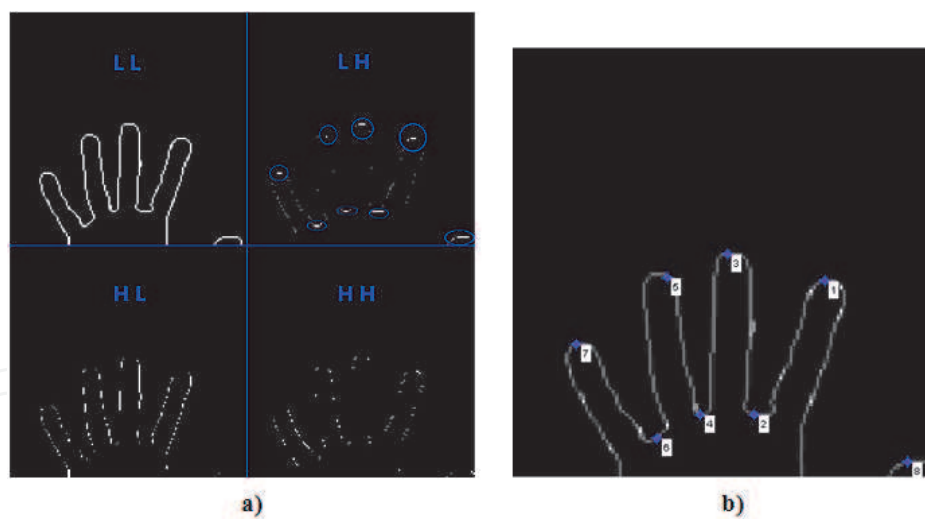


Fig. 9. Information on LH subband. a) Horizontal information and b) The eight control points.

The hand top points are defined by Equation 1 and the hand valleys points are defined by Equation 2.

$$Top_points = \{P_1, P_3, P_5, P_7, P_8\} \quad (1)$$

$$Valley_points = \{P_2, P_4, P_6\} \quad (2)$$

After the calculation of control points a vector with 31 W wavelet features is computed, the vector is called FV . The vector is divided into six sections as it is shown in Equation 3.

$$FV = \{f_1, f_2, f_3, f_4, f_5, f_6\} \tag{3}$$

The first group of eight features f_1 is obtained with the Euclidean distance measures between the eight control points and O' obtained in Fig. 9. The equation 4 show the computation of the first group of eight features.

$$f_1 = \{w_1 = \overline{p_1O'}, w_2 = \overline{p_2O'}, \dots, w_7 = \overline{p_7O'}, w_8 = \overline{p_8O'}\} \tag{4}$$

The first group of features f_1 is shown in Fig. 10.

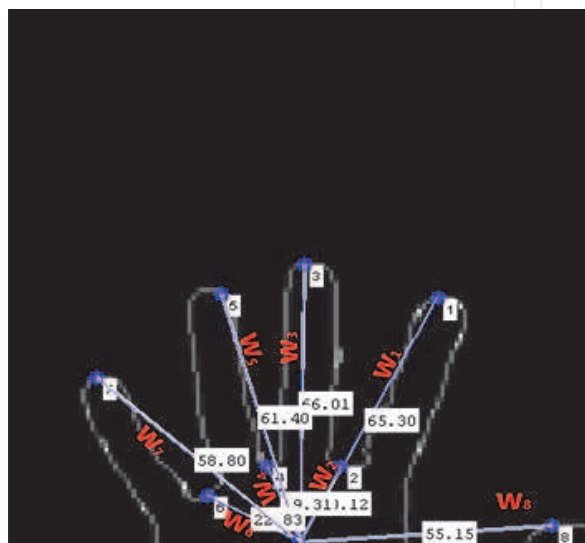


Fig. 10. The group of features f_1 .

The second group of eight features f_2 is obtained with the computation of the angle between the eight control points and O' , the angle is calculated with respect to the horizontal line. The equation 5 show the computation of the second group of eight features.

$$f_2 = \{w_9 = \angle p_1O', w_{10} = \angle p_2O', \dots, w_{15} = \angle p_7O', w_{16} = \angle p_8O'\} \tag{5}$$

The second group of features f_2 is shown in Fig. 11.

The third group of features f_3 is obtained by means of a triangulation of the Euclidean distances between the points p_1, p_2, p_6, p_7 . The equation 6 show the computation of the third group of three features.

$$f_3 = \{w_{17} = \overline{p_2p_7}, w_{18} = \overline{p_7p_1}, w_{19} = \overline{p_1p_6}\} \tag{6}$$

The third group of features f_3 is shown in Fig. 12.

The fourth group of features f_4 is obtained by the computation of the Euclidean distances between the four fingers of the hand excluding the thumb. The equation 7 show the computation of the fourth group of six features.

$$f_4 = \{w_{20} = \overline{p_1p_2}, w_{21} = \overline{p_2p_3}, w_{22} = \overline{p_3p_4}, w_{23} = \overline{p_4p_5}, w_{24} = \overline{p_5p_6}, w_{25} = \overline{p_6p_7}\} \tag{7}$$

The fourth group of features f_4 is shown in Fig. 13.

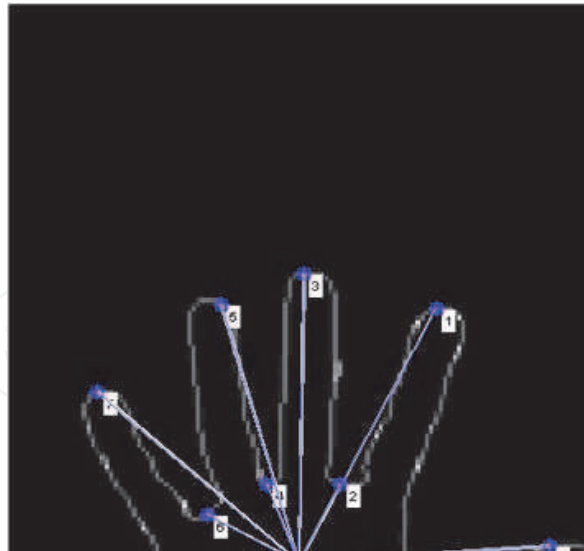


Fig. 11. The group of features f_2 .

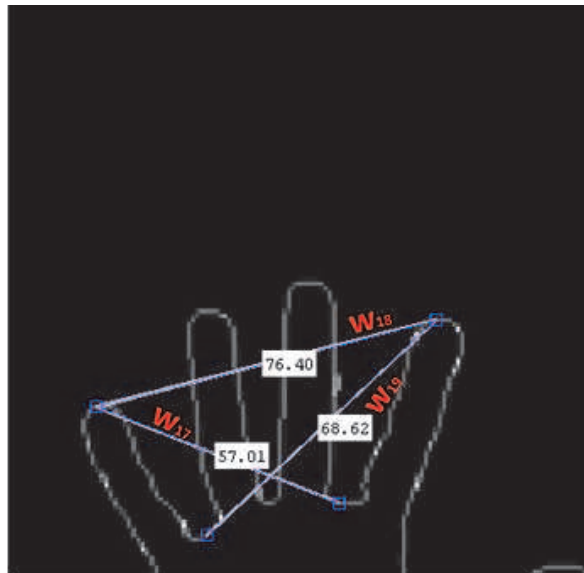


Fig. 12. The group of features f_3 .

The fifth group of features f_5 is obtained by the computation of the Euclidean distances between the valleys of the hand which are distinctive features of each individual. The equation 8 show the computation of the fifth group of three features.

$$f_5 = \{w_{26} = \overline{p_2 p_4}, w_{27} = \overline{p_4 p_6}, w_{28} = \overline{p_6 p_4}\} \quad (8)$$

The fifth group of features f_5 is shown in Fig. 14.

The final group of features f_6 is obtained by the computation of the Euclidean distances between the thumb p_8 , middle p_3 and pinky p_7 fingers with respect to O' . The equation 9 show the computation of the sixth group of three features.

$$f_6 = \{w_{29} = \overline{O' p_3}, w_{30} = \overline{p_3 p_7}, w_{31} = \overline{p_7 O'}\} \quad (9)$$

The sixth group of features f_6 is shown in Fig. 15.

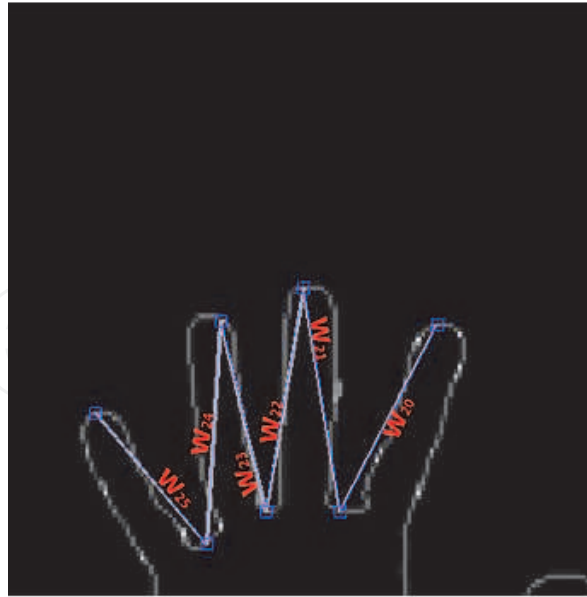


Fig. 13. The group of features f_4 .

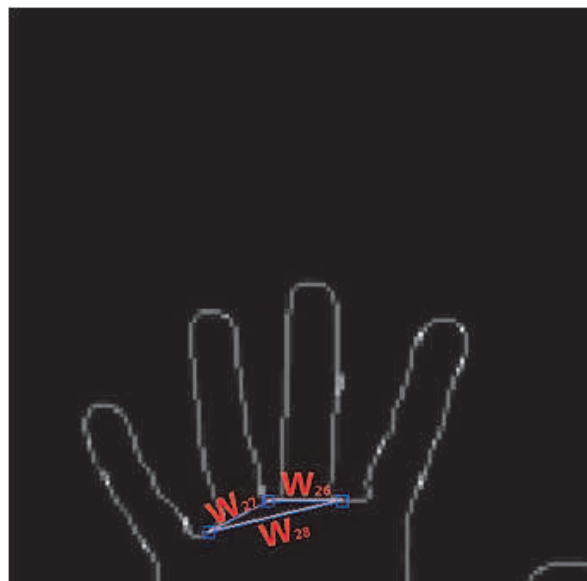


Fig. 14. The group of features f_5 .

3.6 Nearest Neighbor classification

For the identification of hand geometry an algorithm of supervised learning called nearest neighbor was used. The examples are divided into training and test. A training example is an ordered pair $\langle x, y \rangle$ where x is an instance and y is a label provided by a supervisor or expert. A test example is an instance x with unknown label. Then, the goal is to predict labels for test examples.

The supervised nearest neighbor algorithm was used for hand classification and works as follows (Samsudin & Bradleya (1988)): first, a database of sample hands images is created, the correct classification (label) for each image is already known, this is called the training phase. Then, when the system is given a query, i.e., a new hand to classify, the system simply computes its distance (Euclidean) to every training example and keep the k closest image in

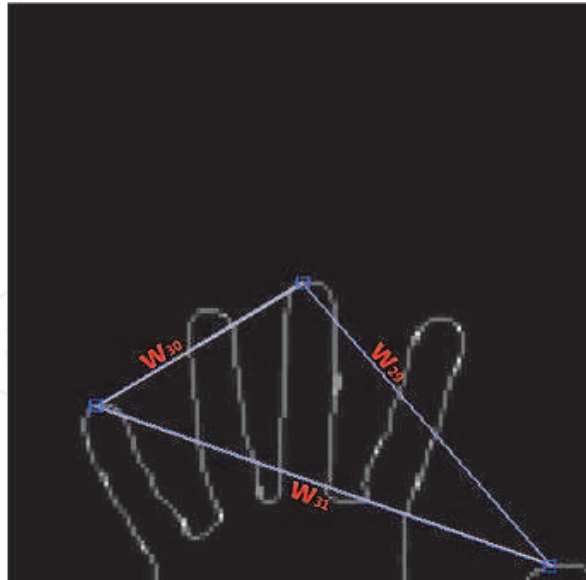


Fig. 15. The group of features f_6 .

the database, in other words, finds the nearest neighbor of the query in the database. The system classifies the query as belonging to the same class as its nearest neighbor.

An example of the results obtained for classification with nearest neighbor algorithm with different wavelet features are shown in Fig. 16.

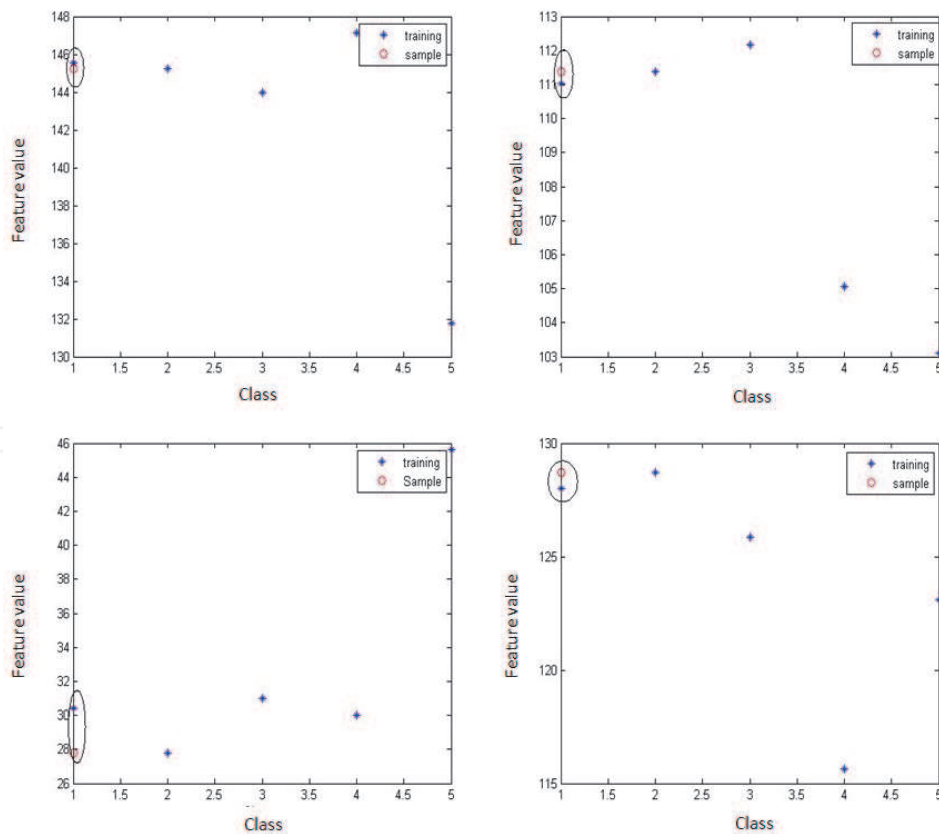


Fig. 16. Nearest neighbor results for features 5, 10, 15 and 25.

4. Experimental evaluation and results

The hand geometry identification system was trained and tested using a database of 120 hand images acquired using a commercial scanner. Additionally, images of the faces of the same individuals were acquired with a web cam and stored and relations with the corresponding hand image. Then, when an input hand is recognized the system returns the face of the corresponding individual.

Four tests were made in order to observe the performance of the hand identification system proposed. 70 random individuals were selected for the recognition phase and a total of ten chances were executed for each person. Three different variables were measured for each of the four tests: false accept rate (FAR), false reject rate (FRR), and recognition rate (RR).

The first test, was made with natural conditions of hand images acquisition. At the second test the hands were exposed to noise by adding to the scanner pen litter. Finally, the third and four test was developed with extreme light conditions, such as high light and darkness. The results obtained for the tests are shown in Table 2.

Conditions	FRR	FAR	RR
Natural conditions	11.4%	10.4%	78.2 %
Participles of noise	30.56%	3.6%	65.84%
High light conditions	27.88%	7.0%	65.12%
Darkness	22.34%	10.0%	67.66%

Table 2. Tests results

The results showed in Table 2 demonstrated the average performance of the system, even when a simple classifier is used. Compared with the results showed in the literature our results are poor but represent a good start in a different new identifications method based on feature extraction on the wavelet domain.

Sometimes, the mistake in recognition is due to the bad position of the hand, even when the pegs are located in strategic positions. In Fig. 17 an example of a mistake in wavelet detection due to bad positioning is shown.

5. Conclusions and further works

A method to solve the old problem of human identification using a biometric cue known as hand geometry was presented. An input image of a hand was obtained using a scanner; the image is preprocessed and transformed to the wavelet domain. In the wavelet domain, 31 hand geometry features were obtained, after that, the input image is tested against 120 images of hands stored on a database. The stage of classification is performed using a simple nearest neighbor algorithm with Euclidean distances, Finally, a total recognition rate of 70.2 was obtained after experimental evaluation.

The proposed methodology can be applied in different environments such: parking lot, cash vault, interactive kiosk, anti-pass back, point of sale, time and attendance, etc.

In the future, and with the goal of obtaining better results, different more robust classifiers and different measurements distances will be tested.

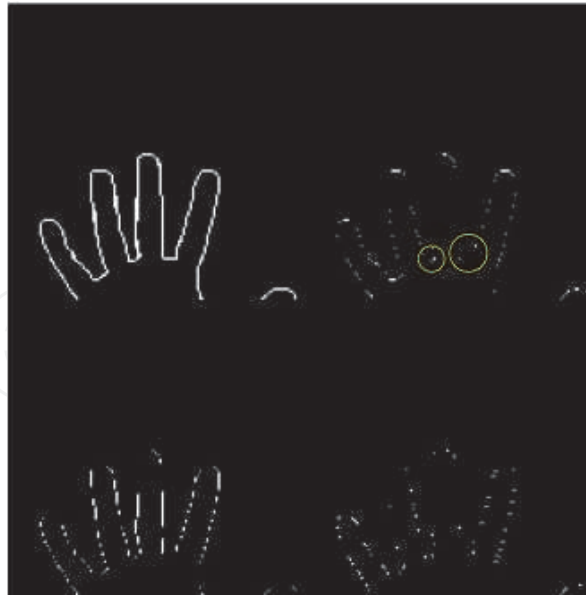


Fig. 17. A mistake in horizontal information detection in wavelet domain due to bad hand positioning.

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Discrete Wavelet Transforms - Biomedical Applications

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The discrete wavelet transform (DWT) algorithms have a firm position in processing of signals in several areas of research and industry. As DWT provides both octave-scale frequency and spatial timing of the analyzed signal, it is constantly used to solve and treat more and more advanced problems. The present book: Discrete Wavelet Transforms - Biomedical Applications reviews the recent progress in discrete wavelet transform algorithms and applications. The book reviews the recent progress in DWT algorithms for biomedical applications. The book covers a wide range of architectures (e.g. lifting, shift invariance, multi-scale analysis) for constructing DWTs. The book chapters are organized into four major parts. Part I describes the progress in implementations of the DWT algorithms in biomedical signal analysis. Applications include compression and filtering of biomedical signals, DWT based selection of salient EEG frequency band, shift invariant DWTs for multiscale analysis and DWT assisted heart sound analysis. Part II addresses speech analysis, modeling and understanding of speech and speaker recognition. Part III focuses biosensor applications such as calibration of enzymatic sensors, multiscale analysis of wireless capsule endoscopy recordings, DWT assisted electronic nose analysis and optical fibre sensor analyses. Finally, Part IV describes DWT algorithms for tools in identification and diagnostics: identification based on hand geometry, identification of species groupings, object detection and tracking, DWT signatures and diagnostics for assessment of ICU agitation-sedation controllers and DWT based diagnostics of power transformers. The chapters of the present book consist of both tutorial and highly advanced material. Therefore, the book is intended to be a reference text for graduate students and researchers to obtain state-of-the-art knowledge on specific applications.

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