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New mobile phone and webcam hand images databases for personal authentication and identification

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Abstract

In this work we created two hand image databases, usingmobile phone cameras and webcams. Themajor goal of these databases is to build upon aperson's authentication/identification using hand biometrics,decreasing the need for expensive hand scanners.Both databases consist of 3000 hand images, 3 sessions x 5 images (per person)x 200 persons, and are available to freely download. The test protocol is defined for both databases; simple experiments were conducted using the same protocol. The results were encouraging for most of the persons (accuracy was greater than 80%), except for those who rotated their hands in an exaggerated manner in all directions.

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1. Introduction

A person's authentication/identification using biometrics has attracted a great deal of researchers' interest recently. This is due to the many applications that make use of biometrics, such as remote log-in to secured systems, securing mobile devices, cars, buildings, in addition to surveillance and terrorist monitoring applications.

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Hand Geometry is one of the physical characteristics that has proved to be a good biometric to identify/authenticate persons.That is because it has several advantages over other biometrics, such as ease of use, being non-intrusive, ease of fusion with other biometrics such as fingerprint and palm, and only a small amount of data being required to uniquely identify a person.Hand Geometry measurements are easily collectibleand can be captured by a simple camera or a special scanner. Hand shape biometrics areuser-friendly and a robust method to deal with both environmental conditions and individual anomalies. Since this technology was first introduced in 1971, a Patent of Ernst and Miller [1] [2], a lot of work has been done.

Most hand biometric systems use pegs to determine the location of a user's hand and to separate the fingers[3]. However, using pegs is inconvenient during image acquisition of users' hands. Pegs make the system not user-friendly; in addition, training is required on how to use the peg system. To avoid these problems, some researchers use peg-free systems.Obviously a system depending on a camera, rather than a scanner, is a *peg-free* system.

Only a small number of hand image databases are available for research; most of them represent only a small number of users, using special and expensive scanners. This work attempts to provide two Hand Image Databases: one is created using a mobile phone camera of modest quality, which we called mobile hand images database (MOHI), and the other is created using a webcam with low quality images, which we called webcam hand images database (WEHI); in addition to setting the test protocols for each database. Both MOHIand WEHIare made freely available through Mutah University website: http://www.mutah.edu.jo/en/colleges/science.html

We opted for low quality images, because they were all we could get with the great availability of low-priced mobile phone cameras and webcams. Such databases allow us (and other researchers) to find out to what extent low quality hand images could be used for authentication/identification systems, and therefore, if it is enough to use just a webcam or mobile phone camera to identify persons.

Reducing the expensive cost of hardware that comes with most biometric systems is essential for increasing the number of users (popularity). This might come about if the results of the work using the low quality images databases were positive. Because of the low quality images, a researcher may opt for using only hand geometry features for authentication/ identification, excluding minutiae and other fine details. Both MOHIand WEHIconsist of 200 male and female users, with three age groups: old, middle and young.Each user's right hand was imaged five times for each of three different sessions for each database, giving 6000 hand images. Hands were imaged with random rotation of the hand, and random opening of the fingers.

The rest of this paper is organized as follows: Section (2) of the paper shows the related work, in addition to a briefdescription of the current hand databases;in Section (3), we describeMOHI and WEHI databases in detail;the test protocol of both databases is described in Section (4),followed by the experimentresults and discussion.

2. Literature review

There is an increasing demand for using handgeometry since it has become one of the most important approachesto biometric systems. Accordingly, many handgeometry-based biometric systems have been proposed to improve hand geometry methods or to investigate new methods to increase the accuracy and reliability of these techniques.

Anil *et al*. [4] and Sanchez-Reillo*et al*. [3]proposedsomehand geometric features, such as width and length of fingers, hand size, and height. The main problem of these methods is that the users must place their hands on a specific plate,withthe fingers between fixation pegs.Using scanners in general incurs some health concerns.

De Santos Sierra *et al*. [5] proposed a feature extraction method that provides fixed hand measurements to previous changes. They used a database containing hand images of 120 different individuals, using a mobile device.The classifiers used were Support Vector Machines (SVM) and k-Nearest Neighbour. Luque-Baena*et al*. [6]used a methodology based on a genetic algorithm,mutual information and hand segmentation approach to extract the hand features. They used several databases and obtained results with a high degree of accuracy.

Guo*et al*. [7] used hand geometrical features for personal identification, employingan infrared illumination device. The users could put their hand anywhere at the head of the camera, with no need for pegs or templates.Their proposedmethod achieved a False Accept Rate (FAR) of just 1.85%.

Saxena*et al*. [8]focused on the lengths and widths of fingers, in addition to the width of the palm. Their study presented an algorithm with a new threshold toseparate the hand from the background image. Their algorithm achieved 97.44% accuracy, and 98.72% accuracyverification.

Mathivanan*et al*. [9]proposed a method to combine 2-D and 3-D hand geometry features,which produced better results. Their experiments were conducted using a database of 150 images taken from 50 persons;the acquiredhand images in this study were contact-free.

Kang and Wu [10]proposed a method using Fourier descriptors for hand shape recognition, which focused onboth finger contour and finger area, to determine the valley and peak points accurately. After that they used score-level fusion based on a weighted sum to get the matching results. Poonam and Sipi[11]proposedusing hand contour matchingwith Euclidian distance to extract hand shape features by calculating the starting reference value and then calculating the finger's peak and valley points. Theirexperiments wereconducted on 300 images, six images per person, three for the right hand and the same for the left.

Gupta and Singla[12] developed a verification method using a database imaged by a camera. The database was collected from five subjects, 10 images for each one, with different phases and illumination. The authentication accuracy of the system was 99.8%. Dhole and Patil[13]proposed anidentification methodby extracting 28 features from the hand. Theimages were taken by a digital camera using a black background behind each hand, assuming that the user's fingers were not to be attached. Each image resolution was 120 dpi. The error rates were 0.48% FAR, and 1% FRR.

Varchol and Levicky[14] used a database consisting of 408 hand images from 24 people (female and male). These images were taken by a scanner with a flat surface. The users put their hands on the surface of the scanner and the palms were controlled by pegs. They used different patternrecognition methodssuch as Euclidian distance, Hamming distance, and Gaussian mixture model for verification. Their experimenterror rates were 0.18% FAR, and 14.58% FRR.

Our work is not intended to compete with the previous work on hand biometrics;rather it is oriented to create new hand databases using available webcams and mobile cameras, to be available for our own future work, and also freely available toother researchers.These databases should mimic real world variations such as hand scale, rotation and light conditions.Thosewere well controlled by the unwantedhand scanners.

2.1. Current hand biometric databases

There are many databases for hand biometrics in the literature; however, most of theseare either not available tothe research community, contain only a small number of images, a small number of users, or have been obtainedusingexpensive scanners.Table (1) shows some of the hand biometrics databases used in the literature. This list is not meant to be exhaustive, nor to describe the databases in detail, but merely to provide an example of the literaturedatabases.

Table1.Summary of some of the hand databases used for biometrics.

Database	#Users	#Images/User	Device Used	Reference
1	642	3	HP Scanjet 5300c scanner at 150 dpi	[15]
2	150 137 100	10 6 6	GPDS desk-scanner IITD: circular fluorescent illumination around camera lens CASIA: CCD camera fixed at the bottom of the device.	[6]
3	9	3	Commercial 3-D scanner.	[16]
4	100	10	Commercial thermal camera called testo 882-3.	[17]
5	5	10	ConventionalCCD cameras.	[12]
6	50	6	The images are captured using a scanner.	[11]
7	50	3	A 3-D digital camera.	[9]
8	86	3	Images are acquired by a commercial scanner.	[18]
9	100	60	One commercial webcam, one infrared (IR) filter, and four sets of double-row GaAs infrared emitting diode with 12 diodes in each set.	[7]
10	100	6	Digital camera and black flat surface used as a background.	[13]
11	70	-	Commercial scanner. The images were taken with a resolution of 300 dpi.	[19]
12	3 DB used: 120 235 287	20 14 10	The first database: so the mobile device (an HTC) Second database: camera resolution of these images is 800x600 pixels Third database: Olympus C-3020 digital camera (1280 x 960 pixels) was used to acquire images	[5]
13	25	10	Color digital camera.	[20]
14	50	10	A flatbed scanner as an input device.	[21]
15	24	17	Low cost, high speed processors and solid state scanner.	[14]
16	2DB used: 9 20	8 6	CCDcolor digital camera, placed at fixed distance above the platform.	[22]
17	70	10	Data collectedusing a document scanner.	[23]
18	20	20	Platform designed for the proposed (CCDcolor camera, placed above a platform)/(image captured is 640*480 pixels color photograph in JPEG format)	[24]
19	50	10	A light source, a camera, a single mirror and a surface (with five pegs on it).	[4]

3. Description of databases

To capture hand images we used twotypes of cameras:

- Mobile phone cameras to create MOHI.
- Webcams to create WEHI.

These databases were designed to be used for different purposes, such as:

- Identification of persons
- Authentication of persons
- To distinguish between male and female
- Classification of people by age groups

MOHI and WEHIimages were taken of the right handsof 200 persons in four different cities, three different sessions each.In each session, five images were captured by a digital camera (MOHI), and another five by a webcam(WEHI) for the same person. The background was a white paper for all images.We could not process more than 200 persons because people were very reluctant about giving their hand images.

To mimic real world variations, we allowed variations in rotation, scale and light conditions. The images were taken in 4 different cities, 50 persons from each city.To measure the accuracy of the system in the case of uncooperative users, we allowed extreme variations in rotation (around X, Y, and Z axes), scale and light in the last group of persons from 51 to 200.

Each image inthe MOHI database was 8 mega pixels (3264 x 2448). Each image in the WOHI database was 2 mega pixels (640 x 480).The time between sessions was about 3 days. The total number of images is 6000 hand images, 3000 for MOHI and 3000 for WEHI.

We followed the following rule for naming the image files:the file name starts with the session number (S1, S2 or S3), followed by the person number (P), followed by gender (male: M or female: F), then the age of the person, and finally the image number within each session from 1 to 5. Table (2) explains the naming system of the files.

Table 2.Examplesof different image file names from MOHI and WEHI databases.

#Example	Session	Subject	Gender	Age	#Image	Image Filename
1	S1	1	Female	11	1	S1-P1-F-11- 1
2	S1	1	Female	11	2	S1-P1-F-11- 2
3	S2	6	Male	40	3	S2-P6-M-40- 3
4	S2	35	Female	36	5	S2-P35-F-36-5
5	S2	103	Female	24	4	S2-P103-F-24- 4
6	S2	182	Male	27	5	S2-P182-M-27-5
7	S2	161	Male	49	1	S2-P161-M-49-1
8	S3	17	Male	45	2	S3-P17-M-45-2
9	S3	77	Male	15	3	S3-P77-M-15-3
10	S3	152	Male	63	2	S3-P152-M-63-2

4. Testing protocol

Both MOHI and WEHI were recorded in 3 different sessions, and both can be used for authentication and identification problems. S1 can be used for training, S2 might be used for testing, and S3 might be used for verification of the test results. It is possible to put this any other way around, as there is nothing special aboutanysession. To increase training data, researchers can use 2 sessions for training and the remaining session for testing, using 3-fold cross validation.

Researchers can use any hand segmentation method, and any feature extraction method, using any classifier. Figure (1) shows a typical system for identifying or authenticating persons using MOHI or WEHI.

To implement this protocol, we opted for a simple identification system, using 3-fold cross validation. For segmentation and classification we used artificial neural network (ANN) with back propagation.

Each hand image contains two different areas, the hand area and the background.The skin colour is different from the background colour, so we opted for our algorithm described in [25], which is based on training an ANN on the colour of the pixel and its 8 neighbours to segment lips from the face. This algorithm is modified to segment pixels to skin or non-skin colour. The algorithm uses fusion of different colour models to form the feature vector that represents the 9 pixels, those obtained from a number of images to train the ANN. Feeding the trained ANN with the feature vectors, which are extracted from the pixels of an input image, segmented the hands perfectly. The accurate segmentation result is due to the colour of the hand skinas distinguished from the background(see Figure (2, middle)).

We used the well-known Canny edge detection [26] method to detect the edges of the segmented hand.Despite there being more than 90 geometry features to choose from, our hand shape feature extraction method focused on the most important 19 feature points (for simplicity), which are represented using the Chain Code Algorithm[27].The Chain Code Algorithm is employed to represent the shape of the hand, because it is not affected by the rotation of the hand[28](see Figure (2, right)).

The 19 selected features include Pinkie length, Ring finger length, Middle finger length, Index finger length, Thumb length, Lower palm length, Upper palm length, Thumb width, Index finger width, Middle finger width, Ring finger width, pinkie width, Pinkie lower width, Ring lower width, Middle lower width, Index upper width, Middle upper width, Ring upper width, and Pinkie upper width.

For training and testing we employed theMatlab'sANN with back propagation, which consists of one input layer with 19 nodes representing the 19 features, one hidden layer with 40 nodes, and one output layer of 200 nodes representing all persons in the database. The same network was used for both MOHI and WEHI.

5. Resultsand discussion

In this paper we are more interested in identifying persons based on their hands, rather than building a secured authentication system, e.g. identifying terroristsfrom their hand coming into view.The previous test protocol was applied on both MOHI and WEHI.

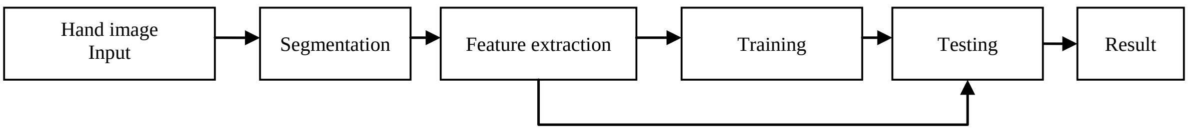

Fig. 1.Typical Hand biometric system.

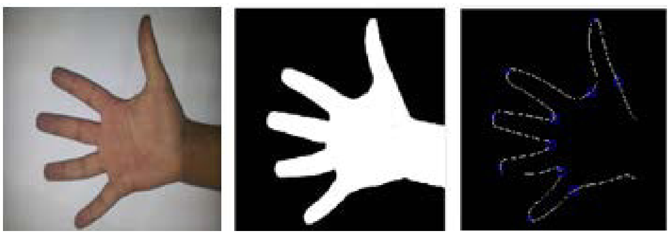

Fig. 2. (left)Original image, (middle)segmentation hand, (right)the extracted features.

Because the last 50 persons in both databases were recorded in extreme conditions of light, rotation and scale, we haveshown their results separately. The results of persons from 1 to 150 are shown jointly. Table (3) shows the results of both MOHI and WEHI.

Table 3.Identification results of MOHI and WEHIdatabases.

Persons	MOHI Accuracy	WEHI Accuracy
(1-150)	0.820	0.813
(151-200)	0.428	0.372

As can be noticed from Table (3), the results of identifying persons from MOHIare slightly better than those of WEHI.This is because MOHIwas recorded using higher quality cameras (8 MP). However, the results werenot significantly higher because we only used geometric features, based on the shape of the hand, which can be well preserved using a webcam (low quality).This experiment proves that a webcam is enough to identify persons using shape features. With some users' cooperation and more features, we might not have the need for expensive hand scanners.

Theaccuracy rate of identifying the first 150 persons was encouraging. However,the accuracyrate of identifying the last 50 persons in both databases was significantly low; this was expected because the 19 features used were not enough to recover the real shape of hands from the damaged shapes resulting from extreme rotation. This situation may happen in real life when trying to identify a person showing a rotated hand in a digital image.

6. Conclusion

Hand geometry using mobile cameras and webcams is a promising biometric.Accuracy can be increased by employing new features and techniques.It is important to increase the accuracy of this biometric, so as to not besolely dependent onhand scanners, which have several disadvantages, such as high cost, large size, not available to all users (particularly home and office users), not user-friendly andpotentialhealth concerns. Knowing that,mobile cameras or webcamsare enough to preserve the shape information of hands.We hope that creating MOHI and WEHI contributes to the perfection of hand geometry biometrics.

The rotation of the hand around the z-axis (the virtual line perpendicular to the palm and the camera lens) does not make any difference, as it can be solved using available methods that are invariant to rotation,whilethe rotation of the hand around the x and y axes produces different positions of the hand, and damages some of its geometry features depending on the rotated angle:the higher the angle, the worse the shape.

It is important to find geometric features that are not affected by such rotations, because sometimes a rotated hand image is the only evidence that is available, e.g. a terrorist's hand image.Our future work will focus on finding such invariant features.

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