HAND SHAPE ALIGNMENT-BASED RECOGNITION METHOD

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Abstract

In this research, a simple method is proposed for recognizing hand shape using shape alignment measurement. This proposed method captures colored hand images using simple scanner device, pre-processes them to extract hand shapes, aligns the extracted hand shapes and produces their point correspondences. Then, it uses "Mean Alignment Error" or MAE criterion to measure similarity/ difference between the aligned hand shapes.

Three different simple methods are involved for: finding point correspondences between the aligned hand shapes, ring artifact removal, and ill-defined wrist region correction. In this research, three cases are studied by testing three pairs of hand images. The first pair of images belongs to the same hand, the second pair of images belongs to different hands, and the third pair is formed by images captured from the same hand but in different poses. The MAE of each pair is computed and compared with a predefined threshold value to make the recognition decision.

The preliminary results encouraging us to address issues that will improve the used methodology and measurements in the future.

Keywords: hand shape, hand contour, procrustes analysis, point correspondences, COG, MAE.

Introduction

The use of hand features as a biometric evidence is not very new, the documentation in the literature is scars as compared to other features like face or voice [1]. The distinct advantages that the hand feature (the geometry or the whole shape information) offers are: (i) hand sensing conditions are less complex, for example, a relatively simple digital camera or flatbed scanner can be sufficient; (ii) it is more robust to environmental conditions and individual anomalies, for example: face imaging is subject to pose or expression or glasses and lighting variations, fingerprint requires good frictional skin, and iris or retina scans require special illuminations and are much less user friendly; (iii) it is user friendlier and less prone to disturbances. Therefore, biometric system based on hand features can be attractive alternative in access control applications due to its unobtrusiveness, low cost, easy interface, and low data storage requirements, [1, 2].

In this study, the case of only and purely hand shape information (defined as the contour data or contour shape♠ [1]) is investigated as discriminative feature for person recognition task. A colored hand image is captured with a common flatbed scanner, and passed through preprocessing sub-steps: binarization, segmentation and thinning; to produce an image contains only the view of hand contour [3]. But some preprocessed images may suffer from problems caused by ring, overlapping cuffs, wristwatch or heavy /light pressure of the hand on the flatbed scanner's surface [1], as shown in Fig.(1). Two alternate methods are used for solving these problems and yielding accurate hand contours. Subsequently, the alignment of hand contours extracted from preprocessed hand images, is performed. This research is organized as follows: in section (II) the proposed methodology for hand shape recognition is presented. Section (III) discusses the computation of hand shape feature and experimental setup. Finally, conclusions are drawn in section (IV).

♠ The shape of object is the object's information invariant to a particular class of transformations (translation, scaling, rotation) [11].

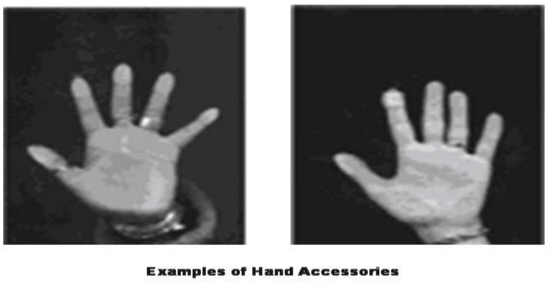


Fig.(1) : Examples of different hand accessories.

Methodology

In this research, the hand shape is the only distinctive feature required to be extracted from the colored hand image for further use in discriminating different persons. This can be done through the following steps: image sensing, image preprocessing, hand shape extraction, and classification step. If some irregularities are produced after the preprocessing step, simple proposed methods are applied for solving them through the hand shape correction step.

1. Image Sensing Step:

A colored RGB hand image which contains the view of the hand and the background whose color is black; is captured by using a common desktop scanner with a flatbed surface. The person places his/her hand –palm facing downwards on the flatbed surface freely where the only needed requirements are not to combine fingers. The captured image is in BMP image file format, and only image of person's right hand is sensed and used in this research [3]. Fig.(2) shows various poses of hand placement.

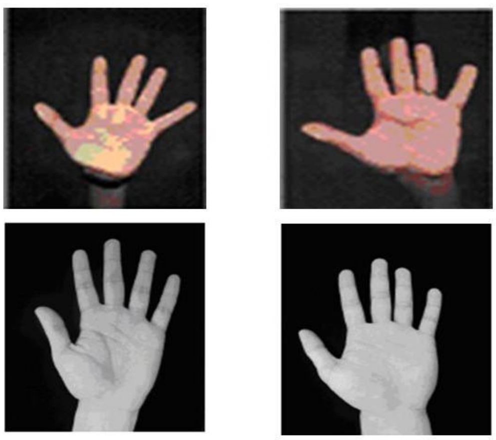


Fig.(2) : Examples of various hand poses.

2. Image Preprocessing Step:

After capturing the hand image, the preprocessing sub-steps are performed as follows: binarization, segmentation and skeletonization [3]. Firstly, since the used image capturing device (scanner) yields basically a two-class image involves the colored hand texture as foreground and the black background [4]. Thus, the colored RGB hand image is transformed into a gray-level hand image; then a very simple thresholding process can be used to transform it into a binary hand image (black/white) by selecting which pixel or point belongs to the background (whose color is black and its value to 0) and which point belong to the foreground (image segmentation) [5], as follows:

$$I'(r,c) = \begin{cases} 1 & \text{for} \quad I(r,c) >= T \\ 0 & \text{for} \quad I(r,c) < T \end{cases} \quad \text{............(1)}$$

Where, I(r, c) is the input image, I'(r, c) is the output image, (r, c) a pixel in the image, and T is the threshold value. The resultant image made of two colors, white color for the foreground and black color for the background. Secondly, an edge detection algorithm based on gradient operator such as (Sobel, Perwitt, Kirstch, Roberts… etc.) is applied to produce the hand contour [2, 3]. Finally, the resultant thick edged hand image is passed through thinning or skeleton zing process to obtain a single-point-width boundary of the hand which is soon named as "Hand Contour" [3]. The thinning process is done by using a simple thinning algorithm which involves the computation of the middle point between each couple of points one of them lies at the rightmost side of the thick edge, and the other lies at the leftmost side of the same thick edge at the same location [3]. This middle point is considered to be the skeleton point of the edge because it satisfies the skeleton conditions :- one point width, passes through the middle of the object, and preserves the topology of the object [6]. Fig.(3), shows an example of preprocessed hand image.

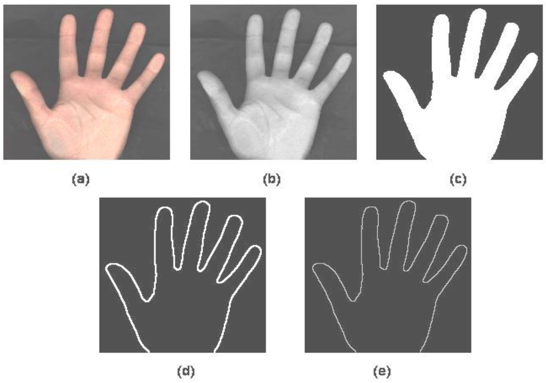


Fig.(3) : a) a colored hand image, b) gray-scale hand image, c) binary hand image, d) edge hand image, and e) single - width or thin edge hand image.

3. Hand Shape Correction Step:

Although hand image preprocessing seems to be the straightforward task, its accuracy may suffer from artifacts due to rings, overlapping cuffs or wrist watch/belts/ chains.

Furthermore, the determination of the hand contour must be accurate enough because the differences between hands of different persons are often very small [2]. For solving such problems and yielding approximately accurate hand contours, the following methods are proposed:

☒ ***Ring Artifact Removal:*** the presence of ring on a finger may create cavity or cause severance on that finger from the palm [1]. A severed finger can be reconnected to its palm by prolonging its both sides in straight lines till they meet the palm, these drawn lines would skim past the sides of the finger parallel to its major y-axis direction.

A cavity or (isthmus) resulted from the faulty segmentation of a ring; this can be detected by monitoring distance between left and right sides of the finger's contour. Any local minima on the left/right side of the finger that its distance exceeds a threshold value, it is assumed to be a cavity caused by ring [1].

This threshold value can be set to the median distance between both left/right sides of the finger at the same location. So, this cavity problem can be simply solved by bridging over the cavities with the drawn straight lines, see Fig.(4).

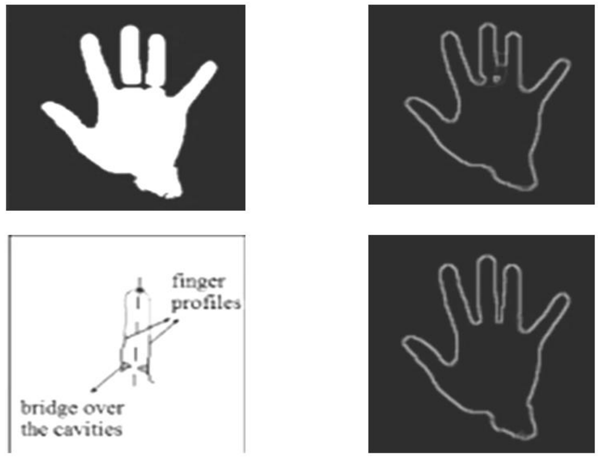


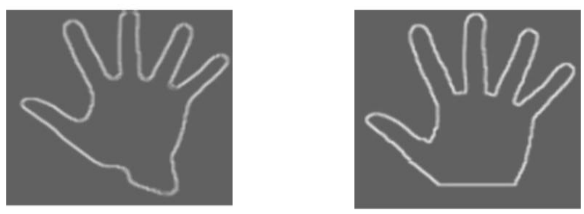
Fig.(4) : An example of ring artifact removal.

☒ ***Wrist Completion:*** If the hand contour obtained after preprocessing step have some irregularities in the wrist region, which occur due to clothing, watch, difference in the angle of the forearm, or the pressure exerted on the scanner.

These factors generate different wrist contours in every session, which can affect the recognition rate [1, 2, and 4].

To solve this problem a uniform wrist region consistent for every hand image is created, this proposed approach can be used: drawing a straight line connects the two sides of the palm.

At first, two end points must be determined, both on the leftmost/rightmost sides of the palm. Then these points would be connected by drawing a straight line started from one of the determined end points and ends on the other corresponding end point on the other side, see Fig.(5).



a) Wrist ill-defined region. b) Wrist completion.

Fig.(5) : An example of wrist completion.

4.Hand Shape Extraction Step:

The shape of an object is represented by a set of discrete points sampled from the internal or external contours on the object itself, and those points are obtained as the locations of edge pixels as found by an edge detector [7]. Thus the shape of the hand is represented by the hand contour points that extracted from the preprocessed hand image. This hand contour is passed to the classification step for further use in matching process.

5. Classification Step:

Given a pair of hand shapes extracted from a pair of preprocessed hand images, as described before, the following hand shape matching paradigm that consists of three sub-steps, is performed :-

A. Hand Shape Alignment:

Aligning shapes enable us to define a simple, yet general ,measure of shape similarity or difference. Finding the point correspondences between two shapes is the analytical (exact) solution to the shapes alignment problem and this is equivalent to finding for each sample point on one shape, the best matching sample point on the other shape [7]. In other words, for each point p_i on the first shape, a "best" matching point q_i must be found on the second shape according to a predefined matching criterion based on shape similarity or difference computation that can be measured by distance measurement, where the bigger distance, is the greater in difference [7].

Therefore, most studies in rich computer vision in the literature dealing with shapes generally agree if **D** is a "distance" function between two shapes **A** and **B**, then the shape **B** is said to be aligned to shape **A** with respect to a transformation group **G** (for example, similarity or difference), if **D** (**A, B**) cannot be decreased by applying to B a transformation from **G** [8, 9]. But these studies differ in the distance function used such as (Hausdorff distance, Strain-Energy, and Least-Squares Type Distance- Procrustes [9]); the least-Squares Distance is mostly used because it provides a convenient way to define a prototype (average) shape from a set of simultaneously aligned shapes [8, 9]. Fig.(6) shows an example of two aligned hand shapes.

Fig. (6) : Alignment of two hand shapes.

Procrustes Analysis

The "prototype" shape of two shapes **A** and **B** is computed as follows [9]: Let $\mathbf{A} = \{(x^A_j, y^A_j)\}$, **j= 1… n**; and $\mathbf{B} = \{(x^B_i, y^B_i)\}$, **i=1…k**. According to a predefined matching criterion, a "*Match Matrix*" **M= {$m_{j,i}$}, j=1..n; i=1…k**; is defined by : **$m_{j,i}$ = "1"** if point $\mathbf{a_j}$ in shape **A** corresponds to point $\mathbf{b_i}$ in shape **B**. Otherwise **$m_{j,i}$= "0"**. Then the correspondences between shapes **A** and **B** can be easily produced by searching the match matrix for point pair matching between the two shapes.

The following proposed point pair matching criterion is pivoted on distance computation of each point on both aligned shapes, relative to a predefined reference point. Firstly, given the segmented hand region in the binary hand image; the reference point is considered to be the center of the hand gravity **COG (x', y')**[♣], see Fig. (7), and it is measured as follows [10]:

$$x'=(\textstyle\sum^{K}_{i=0} x_i)/K \text{ and}$$
$$y'= (\textstyle\sum^{K}_{i=0} y_i)/K \quad \text{.....................................(2)}$$

Where, $\mathbf{x_i}$, and $\mathbf{y_i}$ are **x** and **y** coordinates of the $\mathbf{i^{th}}$ point in the hand region, **K** denotes the number of points in the hand region. Secondly, the distances of points on the aligned shapes relative to this reference point are measured by the Euclidean Distance function, as follows [2]:

$$D=\sqrt{(x-x')^2+(y-y')^2} \quad \text{................................(3)}$$

Where, **(x, y)** are of each point on shapes **A** and **B**. Thus, the resultant correspondences are defined as those points on both aligned shapes, that have the same distances relative to the reference point **(x', y')** and their matching scores in the match matrix **M** set to "1". But

♣ COG: the center of gravity is invariant to transformation such as (scaling, rotation and translation) [12].

the points have no correspondences are considered as outliers, and their matching scores in the match matrix **M** set to "0" [9]. In other words, if **D** (p_i, Reference Point) = **D (q_i, Reference Point)**, then $\mathbf{p_i}$ and $\mathbf{q_i}$ are correspondences and they construct new shape named as **S**; otherwise, they are outliers. Where $\mathbf{p_i} \in$ shape **A** and $\mathbf{q_i} \in$ shape **B, S** is the produced "prototype shape", and **D** is the distance function.

Fig.(7) : The center of gravity of hand region COG.

B. Mean Alignment Error Computation

Given the newly produced shape $\mathbf{S= \{s_i\}=\{(x^S_i, y^S_i)\}}$ **i=1..V**, which is the prototype of the two aligned hand shapes **A** and **B**; the first step of matching process is performed by computing the sum of squares measurements between the corresponding points on **S** in the "Euclidean" plane [7]. Then, the **Mean Alignment Error (MAE)** is computed as the average of the computed sum, as follows [7] :

$$Sum = \sum_{i=1}^{V-1} [(x^S_i - x^S_{i+1})^2 + (y^S_i - y^S_{i+1})^2] \quad \text{...............................(4)}$$

$$MAE = Sum/V \quad \text{......................................(5)}$$

C. Matching

The pair of aligned hand shapes are said to belong to the same hand if their MAE is smaller than a predefined threshold value T; otherwise, they are belong to different hands [8]. If MAE =0, then the pair of aligned hand shapes are exactly identical, [7, 9].

Results and Discussion

Preliminary tested data set contains three pairs of right hand images belong to three different persons. The images are with the size of 1600×1200 pixels, and captured by a simple flatbed scanner named as (Canon Cano Scan LIDE 25) using a resolution of 150 dpi.

There are no pegs to restrict the hand position on the scanner's surface solely not to combine fingers; and there are no restrictions on hand accessories like rings, wrist watches. In order to study the effectiveness of this hand shape recognition method, each pair of hand images represents a case of study. The first pair is tested for the type of matching two hand images belong to the same hand, the second pair is tested for the type of matching two hand images belong to different hands; and the third pair is tested for the type of matching two scans of the same hand but in different poses. For each pair, the methodology in section (II) that constitutes four steps is applied and the MAE value is compared with a predefined threshold value as shown in Figs. (8, 9, and 10).

Experimentally, in order to select the proper threshold value for matching tests, several threshold values that rely on the range of [1...2] are selected. But the best chosen threshold value (T=1.7) sets in the case of no hand images are recognized as the same hand wrongly, and no hand images are recognized as different hands wrongly.

Fig.(8) : shows the first pair of hand images that belong to the same hand, figures 8-a and 8-b show the preprocessed hand images. Figures 8-c and 8-d show the alignment process and MAE computation, MAE=1.2.

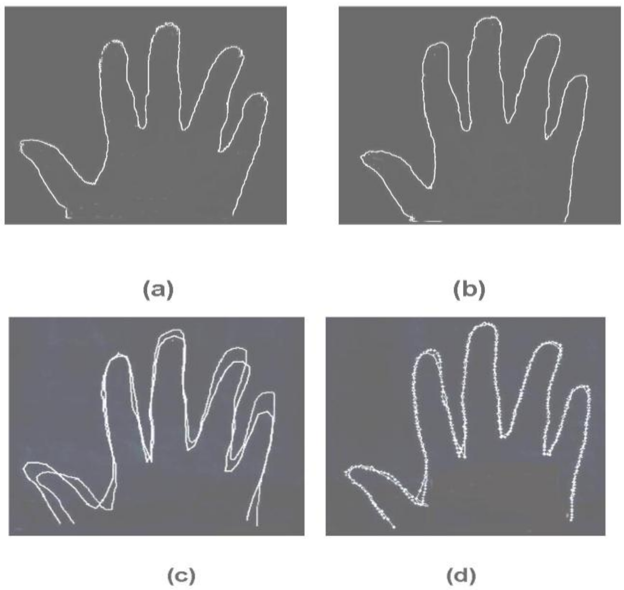


Fig.(8) : Matching of two hand shapes captured from the same hand.

Fig.(9), shows two scans of different hands, Figs. (9-a and 9-b) show the original images after the preprocessing steps, Figs. (9-c and 9-d) show their alignment process and MAE computation, MAE=1.8.

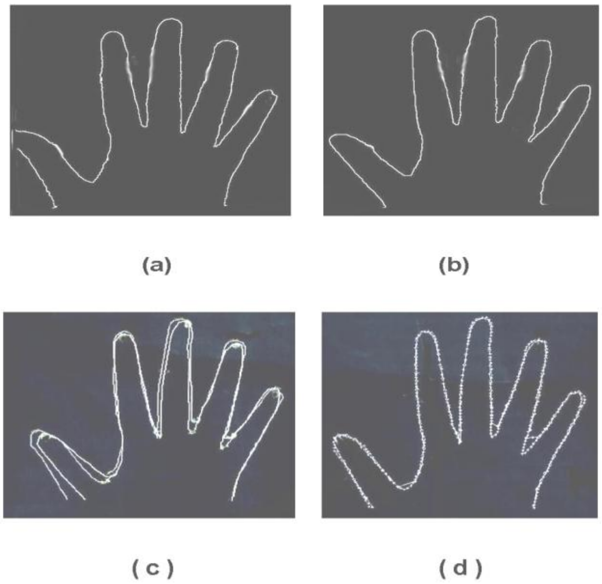


Fig.(9) : Matching of hand shapes acquired from two different hands.

Figs.(10-a and 10-b) show two preprocessed images for two different hand poses acquired from the same person. Figs. (10-c and 10-d) show the alignment process and MAE computation, MAE=1.635.

Notice that, the experiments mentioned above are based on a single training set of sample images for each person; in order to investigate the proposed methodology only for recognizing the person's hand depending on its shape.

Several other paths of research remain to be explored and investigated, especially in both hand identification and/or authentication modes, these are:

- A set of population size up to 3 or more persons can be performed.
- For the enrollment process, multiple independent recordings of person's hand (training samples) can be tested, when each person undergoes (2 or more) hand scan sessions at different times, and between these sessions, the subject can add or remove rings or roll up/ roll down sleeves.

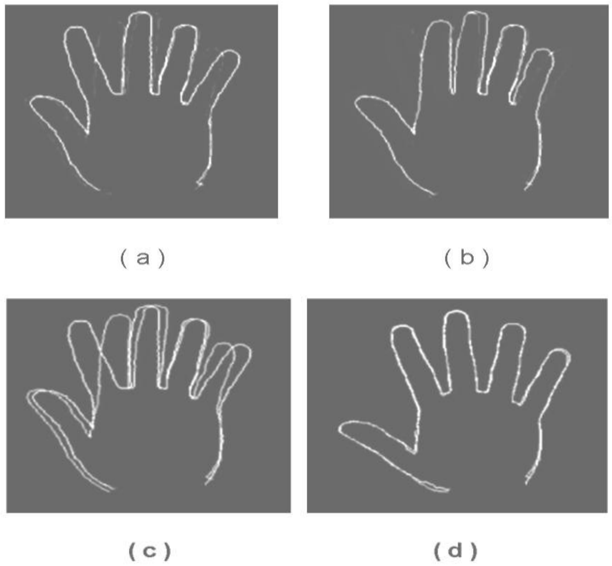


Fig. (10) : Matching of two different hand scans acquired from the same hand.

- The use of images belonging to both person hands (left and right hands) can be studied, to determine the limitations in classification performance.
- The hand texture and/or the palm print, in addition to the hand shape can be judiciously combined to enhance the recognition method.
- Other distance measurements such as: Hausdorff distance [1, 4], and other feature extraction schemes like axial radial transform ART [1, 4, 7] can be used as well as more imaging scenarios.

Conclusions

Since the alignment transform of two shapes is an important part of shape-based object learning and recognition topic. Thus, this research has investigated that the hand shape can be for recognizing individuals by using a simple shape alignment-based recognition method.

This proposed recognition method involves: pre-processing of colored hand images, extraction of hand shapes alignment of extracted hand shapes and computation of their MAEs.

Furthermore, this method does not suffer from confounding factors of rings and ill-defined wrist regions, because it involves solutions for such problems.

Preliminary tests consist of three pairs of right hand images: the first pair belongs to the same hand while the second pair belongs to different hands, and the third pair is formed by different hand scans of the same hand but in different poses.

For each pair, this method is applied in order to obtain set of point correspondences that forms a prototype hand shape from the aligned hand shapes. Once the correspondences are found, the MAE value is computed for discriminating hand images of each pair. Then the recognition method is based on the comparison of each MAE value with a predefined threshold value.

The resulted MAEs for the tested pairs of hand images are: 1.2, 1.8, and 1.635 respectively. The used threshold value sets to 1.7.

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الخلاصة

يقدم هذا البحث طريقة لتمييز الاشخاص من خلال اشكال ايديهم باستخدام طريقة تراصف الاشكال و التي تتضمن التقاط صور ملونة لأيدي الافراد بواسطة جهاز الماسح الضوئي، و معالجتها لاستخلاص اشكال الأيدي منها. ثم عمل تراصف او اصطفاف للأشكال المستخلصة و ذلك لايجاد نقاط التطابق فيما بينها. كما تم استخدام المعيار المسمى بـــ (متوسط او معدل خطأ التراصف) او Mean Alignment Error -MAE لقياس مدى التشابه او الاختلاف بين الاشكال المتراصفة.

اضافة الى ذلك فان الطريقة المقترحة تقدم حلولا بسيطة لمعالجة بعض المشاكل مثل : ايجاد نقاط التطابق بين الاشكال المتراصفة، شكل اليد غير المنتظم الناجم عن أثر الخواتم في اصابع اليد و منطقة رسغ اليد غير المنتظمة بسبب لبس ساعة اليد او الملابس ذات الاكمام الطويلة.

كما تم في هذا البحث دراسة ثلاث حالات معينة و ذلك باختبار ثلاثة أزواج من صور اليد. الزوج الاول يتكون من صورتين لنفس اليد، و الثاني يتضمن صورتان ليدين مختلفتين، أما الزوج الثالث فيتكون من صورتان تم التقاطهما لنفس اليد و لكن في وضعين مختلفين. و قد تم احتساب قيم MAE لكل زوج من هذه الصور و مقارنته بقيمة معينة معرفة مسبقا و ذلك لاقرار مدى التشابه او الاختلاف بين هذه الصور. لقد كانت النتائج الاولية لهذا البحث مشجعة مما دعانا الى تحديد بعض الجوانب التي تطور هذه الطريقة و المعايير المستخدمة فيها مستقبلا.