User Authentication Using Hand Images

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Abstract: ***Hand geometry is recently realized as the biometric modality for personal authentication. Hand geometry has been adjudged to be one of the safest biometric modalities due to its strong resilience against the impostor attack and also one of the easiest modality as per the acquisition. This paper presents an approach for the biometric based authentication using hand geometry from hand images. The proposed biometric system includes enrollment where the hand images are collected, normalization of image, extraction of normalized contour and extraction of palm region .The ROI extracted after the normalization of image. The contour of the hand region from ROI is used to extract structural features that describe the shape of the hand. These features of the known and the unknown users are matched using support vector machine classifier at the verification stage.***

Keywords: Pre-processing, Contour, Features, Inertia Matrix**.**

1. Introduction

The biometric based authentication addresses the automated recognition of individuals, based on their physical and behavioral characteristics. The broad class of human verification schemes, denoted as biometrics encompasses many techniques from computer vision and also in pattern recognition. The personal attributes which are used in a biometric identification system can be physiological or behavioral. Some of physiological characteristics are based on facial features, fingerprints, iris, hand and finger geometry; and some of behavioral characteristic of an individual are voice print, signature, and keystroke style.

A good quality biometric should have: Uniqueness, universality, Permanence, Measurability. The authentication of a person can be done in two modules Identification and Verification. In the identification process the individual presents the required biometric feature and the system associates an identity to that Individual. However, recognition or verification checks the knowledge base of persons. The biometric system then verifies whether that identity is associated with that individual's biometric feature or not.

2. Why Hand Geometry

Hand geometry based systems can be helpful in many security applications. Together with fingerprints and palm prints in a multi modal system it can prove very effective in high security applications. While taking the data for hand geometry, the data for both palm prints and fingerprints can be collected simultaneously. There is no hassle to the user as the accuracy of the system may be greatly enhanced due to the addition of numerous features. The currently existing systems for high security applications use fingerprints of all fingers. They do not consider features of the palm-print or the geometry of the hand. The systems available for palm-prints also ignore the geometry of the hand. Hand geometry is found to be very useful in multi modal systems. Most of the available systems for hand geometry use pegs for setting up the placement of the palm on the scanner. The proposed system aims to get rid of this restriction by allowing the user to vary the positioning of the palm on the scanner. Incorporation of this modality in the current biometric systems for fingerprints and palm prints is trouble-free as the hand geometry is acquired in the peg-free environment.

Hand - based biometric is easy to use and it is less vulnerable to disturbances and insensitive to the environmental settings and to individual anomalies. In contrast, face recognition is known to be quite susceptible to facial accessories, pose, lighting variations and expression; iris or retina-based recognition requires special illumination and is much less responsive; fingerprint imaging requires high-quality frictional skin, etc., and up to 5% of the population may not succeed to get enrolled. Therefore, validation based on hand shape can be an attractive substitute due to its unobtrusiveness, easy interface, low-cost, low data storage requirements.

Biometric systems based on hand geometry are becoming more and more popular due to their uniqueness, universality and most prominently their resistance against the fraud attacks. Since hand geometry is a concealed part of the human body, it is not susceptible to loss or stealing like passwords and it is nearly impossible to duplicate the precise geometry. Other skin attributes like, color, moles, hair, etc, do not affect on hand geometry based systems.

In this thesis, the shape of the hand is explored as a characteristic personal trait for a confirmation task. Despite the fact that the use of hands as a biometric evidence is not very new, and that there are a growing number of commercial products actually implemented, the documentation in the literature is limited as compared to that on other biometrics like voice or face.

3. Overview of Proposed Biometric System

A block diagram of the biometric system is shown in Figure 1. There are two phases of a hand biometric system; one is Enrollment phase and another is Verification phase. Three important steps in hand geometry biometric system are preprocessing, feature extraction and Matching. The steps during the enrollment phase include; preprocessing, feature extraction and storing all the extracted features in a database.

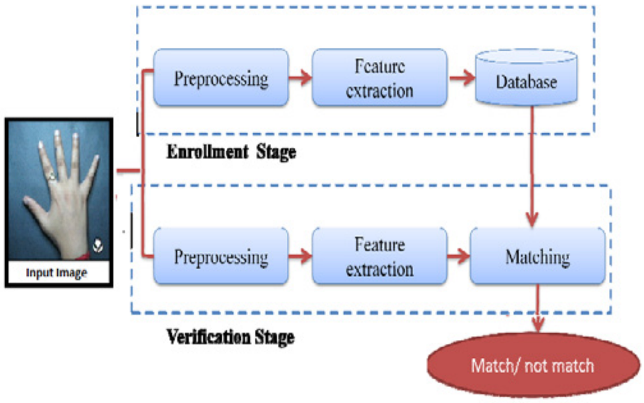

Figure 1: A block diagram of a biometric system

Preprocessing module is the most important part of a biometric system. If an image is preprocessed incorrectly then the results will be worst. Here an image is processed then all the operations are done which are necessary for feature selections are performed. Out of these operations image separation of hand image from the background, Localizing hand extremities and contour extraction are also included.

Second module of the enrollment phase of a biometric system is feature extraction. In this five finger contours from valley to tip and finger widths from three positions and finger lengths are measured. Third module of the enrollment phase of biometric based authentication stores all the extracted features in a database. Here we have stored all the features of each image of every user in the database. In the proposed system we have used text files to store all extracted features. At the verification phase, a user is verified using his currently taken image. Note that all the steps are same as performed at the enrollment phase leaving storing the features in database. Now the extracted features are matched with the previously stored feature vectors.

4. Data Collection

The database used contains 480 images of right hands of 48 users, 10 images for each user. These images were collected at the Biometric research lab IIT-Delhi. Each image is a 768 x 576 pixel color photograph in PNG format. The users are of different age, sex, and colors. Also the images are taken at different time, place, and at the different positions of hand. There is no peg restriction posed on a user. Individual is free to put their hand in any direction and in any position also there is no any restriction on Individuals that they should remove their hand or finger accessories like ring, wrist watch and bracelet. At the time of collection of hand images all kind of possible hands positions were involved.

5. Preprocessing

The major task of preprocessing is to normalize the image which includes the following major steps:

- Image Segmentation
- Detection of Important Points
- Contour Detection
- Normalization of contour

We had taken the background different from the skin color so that it helps us in the segmentation.

5.1 Image Segmentation

During segmentation we extract the hand region from the background. The Extraction hand region is relatively easy task. Image segmentation basically involves separation of the hand region from the background region which includes separation and ring effect removal. Removal of the ring effect and the effects due to isthmus is relatively tough task than the extraction of hand image.

5.1.1 Separation

For the image segmentation, using the thresholding operations we detect the skin color and separate the hand region from the background region. If Ir, Ig and Ib denote the red, green and blue values respectively. Then we make the following comparison to detect the skin.

If (Ir < Ig and Ig < Ib and Ir < 150)
Img (Channel 1) = 0, Img (Channel 2) = 0,
Image (Channel 3) = 0
else
Img (Channel 1) = 255, Image (Channel 2) = 255,
Image(Channel 3) =255

After that we convert Image to gray level image. Next we convert the resultant image into binary image, which may contain some noise. Using morphological operators the noise can be removed easily. The original hand image and the separated image (hand region and background) are shown in Figure 2 which shows the contours if we don't perform normalization.

Figure 2: Original Image and Separated Image

5.1.2 Ring Effect Removal

If a ring is present on the finger of an individual then it may create disconnection between palm and finger. This finger can be found out easily. For this, we calculate the size of the connected components and identify the finger as the smaller part of the hand.

5.1.3 Contour Extraction

For the extraction of contour we first find the major axis of a hand in the direction of the largest Eigen-value of inertia matrix. Inertia matrix can be calculated as follows:
Let us compute the moments of binary image

$$m_{i,j} = \sum_{(x,y)\in objects} \sum x^i y^j \quad (1)$$

Here summation runs over the object pixels. The centroid is defined as

$$\bar{x} = \frac{m_{1,0}}{m_{0.0}} \quad (2)$$

$$\bar{y} = \frac{m_{0,1}}{m_{0,0}} \quad (3)$$

Thus the central moments can be written as

$$\mu_{i,j} = \sum \sum (x - x_1)^i (y - y_1 \quad (4)$$

Now the inertia matrix I is given by

$$\begin{bmatrix} \mu_{2,0} & \mu_{1,1} \\ \mu_{1,1} & \mu_{0,2} \end{bmatrix} \quad (5)$$

Orientation of the object is given by the angle

$$\theta = 0.5\arctan(\frac{2\mu_{1,1}}{\mu_{2,0} - \mu_{0,2}}) \quad (6)$$

The reference wrist point is determined as the intersection of hand's boundary with the ray, which is aligned in the hand direction and originates from the hand's centroid. Once the first intersection is found then the intersection point is set as the start point of the contour, successive contour points are found by following the nonzero neighbors in the clockwise direction. In this way we obtain the hand contours.

5.1.4 Hand Extremities

Detection of hand extremities, i.e. finger tips and valleys is an important step in the feature extraction. Valley is the lowest point between the fingers. The extremities are determined by using high curvature on the contour of the image. But these extremities are sensitive to contour irregularities such as fake cavities and kinks. So we use another technique which draws a plot of radial distance from the reference point around the wrist. This reference point was the first point of the major axis with the wrist line. The resulting sequence involving radial distances yields maxima and minima. These are not affected by the kinks and irregularities of contour and also these maxima and minima are related to extremities which are nine as shown in Figure 3.

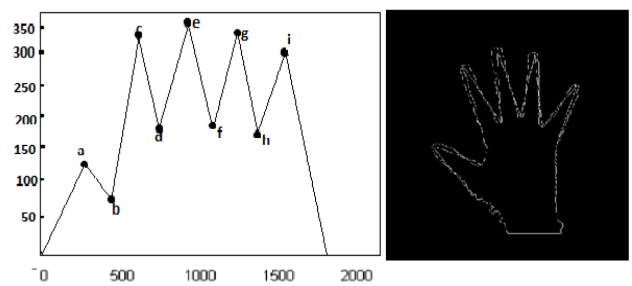

Figure 3: Determination of Extremities

5.1.5 Finger's Information Matrix

It is a 5x3 matrix which contains all the information about finger's of a hand shown in Figure 4. The 2nd column corresponds to contour indices of finger tips. The 1st and 3rd columns correspond to contour indices of surrounding valleys of the particular tip. The indices are in increasing order along each row. The first row corresponds to the thumb, others are ordered in the successive rows clockwise about the hand

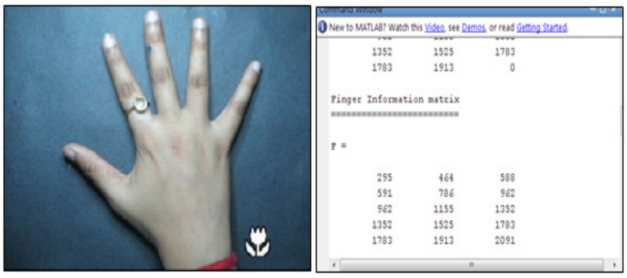

Figure 4: Determination of Extremities

Now we have enough information to remove ring cavity from hand contour and finger's information matrix. Cavities are detected by extracting the finger profiles, i.e. 1D distance curves of contour segments with respect to finger's central major axis. Each finger has two profiles on either side of the finger, left valley to tip, and tip to right valley. The cavities correspond to locations where profile drops below 0.75 of its median and they are morphologically bridged by fitting a line segment on it. So in this manner we remove the ring cavity.

Presence of isthmus can be identified by contour distance from fingers major axis. When this distance either on left and/or right side of the finger exceeds a threshold, it is assumed to be a cavity. It is removed by bridging over the cavity.

Figure 5: Final Segmented Image

5.2 Image Normalization

Now our aim is to normalize the hand binary image obtained from the segmentation step. This normalization is required as individuals are free to put their hand in any direction in a peg-free system. Normalization of hand image involves registering of hand image, which in turn involves global rotation and translation as well as re-orientation of fingers along the standard direction. The process of registration is done using the following steps:

- Translation of the centroid.

- Rotation in the direction of largest eigenvector of the inertia matrix.

5.2.1 Extraction of Fingers

Starting from the finger tip of any finger we move along the boundary of the finger to reach up to the adjacent valley points. Shortest of these is chosen and then it is swung like a pendulum towards the other valley point. This will be utilized to determine the finger length and also shape of the finger as explained subsequently.

5.2.2. Pivots of Finger

Pivots are located by extending the length of the fingers. This way we get the finger pivots and then we plot Hand Pivotal Axis as defined in the next step. We also find the pivot of thumb in the similar manner. Overall we get 5 pivots.

5.2.3. Hand Pivotal Axis

The four pivot points located are joined together either by drawing a line by least squares method or simply joining the last two pivot points to get the hand pivotal axis which is critical in finding the rotation of the hand geometry.

5.2.4 Rotation of the finger

For this, we first calculate the major axis of each finger from its inertia matrix and then its orientation angle Ψ_i. Each finger i is rotated by the angle $\Delta\theta_i = \Psi_i - \theta_i$. Here θ_i the desired orientation of finger. The finger rotation is affected by multiplying the position vector of finger pixels by the rotation matrix $R_{\Delta\theta}$ given by

$$R_{\Delta\theta} = \begin{bmatrix} \cos\Delta\theta & -\sin\Delta\theta \\ \sin\Delta\theta & \cos\Delta\theta \end{bmatrix} \quad (7)$$

5.2.5 Processing for the thumb

The motion of the thumb is rather more complicated as it involves rotations with respect to two diverse joints. In fact, both the metacarpal-phalanx joint as well as the trapezium-metacarpal joint participate in the thumb motion. We have addressed this relatively complicated motion by a rotation followed by a translation. This difficulty arises from the fact that the stretched skin between the thumb and the index finger confuses the valley determination and thumb extraction. For this purpose, we rely on the basic hand anatomy. A line along the major axis of the thumb is drawn and a point on this line from the tip of the thumb to 120% of the size of the little finger forms the thumb pivot. The thumb is then translated so that its pivot coincides with the tip of the hand pivot line, when the latter is swung by 90 degrees clockwise. The thumb is rotated to its final orientation and brought back to the original position.

5.2.6 Normalized Image

After normalizing a finger, the hand is translated so that its centroid, which is the mean of four finger (index, middle, ring, little) pivot points, is taken as the reference point on the image plane. The whole hand image is rotated so that its pivot line aligns with the chosen orientation. Otherwise, the hands could be registered with respect to the major inertial axis and centered with respect to the centroid of the hand contours (and not the pivotal centroid).

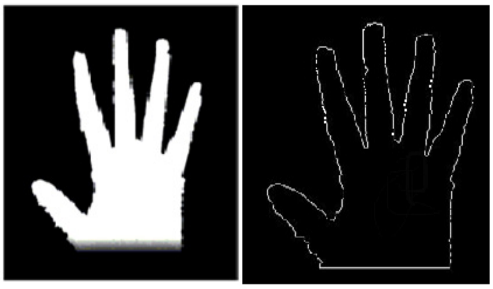

Figure 6: Normalized Fingers and Hand

After finding the normalized hand image we find contour of the normalized image as shown in Figure 6.

6. Feature Extraction

Set of features also named **feature vector**. Transforming the input data into a set of features is called **feature extraction**. The preprocessing module is used to prepare the image for feature extraction. The function of this module is to extract and store features from the input image. The output of the feature extraction module is the measure of features like finger length, finger width, palm width etc.

The hand geometry-based authentication system relies on geometric invariants of a human hand. Typical features include length and width of the fingers, aspect ratio of the palm or fingers, thickness of the hand, etc. To our knowledge, the existing commercial systems do not take advantage of any non-geometric attributes of the hand, e.g. color of the skin.

There are several features that can be extracted from the geometry of palm. We are interested only in those features that are consistent, i.e. features that are insensitive to hand pose variation. The extracted features used in this work are the length of each finger including thumb, the width of each finger at 3 locations and four distances from a fixed point on the palm to tip of each finger. This results 24 features all together
.

6.1 Finger Length

In the present biometric system we have normalized the hand image by normalizing each finger individually and the palm region. First each finger is cut off from the palm. Cut is defined as the straight line connecting the two ends of finger's contour segment. The start point and the end point of finger are two adjacent valley points of finger which are obtained from 5 x 3 finger information matrix given in section 3.1.5. Fingers are cut by drawing a binary line of zeros on the shape image and applying the connected components algorithm, the larger label is taken to be the palm and the other one to be the finger being removed. Distance from the finger tip to the mean of start and end point gives the length of the finger. This step is repeated for each finger for determining the length.

Algorithm for finger length extraction

Input: finger information matrix, binary image, hand's boundary contour

Output: finger length

1. Find the start point and the end point
   - Draw-line between the start point and the end point
   - Find the mid-point of line.
   - Find the distance between the finger tip and the mid point
2. Repeat Step 1 for each finger.

6.2 Finger Width

As we discussed in Section 6.1 normalization, we have removed each finger from the palm. For extracting the width of the finger we have used the finger contour and finger tip of the removed finger. Using the finger tip point obtained from the 2nd column of finger information matrix, we get the finger tip position on the contour. From this point, we move in both directions 35 pixels along the contour of the particular finger and calculate the distance between these two points, which is clearly the width of the finger 35 pixels far from the finger tip. At each 35 pixels apart we calculated it three times.

Algorithm for finger width extraction

Input: Finger contour, finger information matrix
Output: Finger width from three positions.

1. Fix finger tip as starting point
   - Move 35 pixels in both (left and right) directions from finger tip.
   - Obtain two points, say A and B
   - Find the distance between these two points.
   - Calculate next two distances in the same way.
2. Repeat Step 1 for each finger.

6.3 Distance from a fixed Point

We have discussed about the pivots of the finger in Section 5.2.2 Pivots are located by extending the length of the fingers towards palm. We fix a point on the palm region at 50 pixels below the middle finger's pivot of normalized image. This point is taken as the reference point for calculating the next four features of hand image. From this reference point we measure the distance from the tip of each finger.

Algorithm for Special distances

Input: Normalized hand image, Normalized contour, Finger information matrix
Output: Four special distances.

- Fix middle finger's pivot as the starting point
- Calculate reference point just 50 pixel below the middle finger's pivot position.
- Calculate the distance from finger tip to this reference point for each finger.

We have calculated the four distances from the finger tips except thumb.

So now we have a total of 24 features: five finger lengths, fifteen finger widths (three for each) and four special distances.

All features are shown in Figure 7.

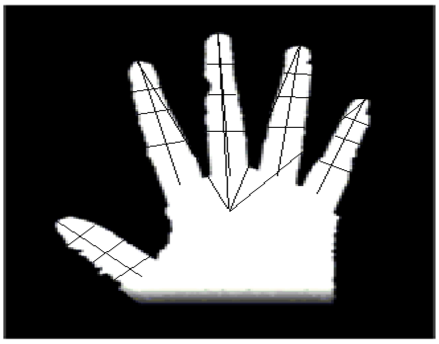

Figure 7: All 24 features

7. Matching and Experimental Results

Hand image is preprocessed and then features are extracted, these features constitute the database. We have already stored features in database. Now the input image is matched with those stored in database. Matching is carried using SVM. We used two class SVM for authentication.

Algorithm for matching:

Step1. Input the Color image.
Step2. Preprocessing of the input image
- Image Segmentation
- Ring Effect removal.
- Normalization of hand image
- Finding Extremities

Step3. Feature Extraction.
Step4. Matching using SVM classifier

7.1 Training and Testing

After feature extraction step, SVM classifier is applied for matching. System works in two parts, training and testing accomplished by SVM [15] classifier. Our matching requires multiclass SVM.

Since SVM supports only two-class Identification, a multi class system can be built by combining two class SVMs. Given a set of training samples, each given class number as belonging to one of two classes, an SVM training algorithm constructs a model that assigns new samples into one class or the other.

7.2 Identification Results

We begin by considering classification problems with only two classes. Formally, each instance I is mapped to one element of the set {p, n} of positive and negative class labels. A classification model (or classifier) is a mapping from instances to predicted classes. Some classification models produce a continuous output (e.g., an estimate of an instance's class membership probability) to which different thresholds may be applied to predict class membership.

Other models produce a discrete class label indicating only the predicted class of the instance. To distinguish between the actual class and the predicted class we use the labels {Y, N} for the class predictions produced by a model.

Given a classifier and an instance, there are four possible outcomes. If the instance is positive and it is classified as positive, it is counted as a true positive; if it is classified as negative, it is counted as a false negative. If the instance is negative and it is classified as negative, it is counted as a true negative; if it is classified as positive, it is counted as a false positive. The propose system was tested on 480 images, in experiment phase 7 images are randomly selected for training and the rest 3 for testing. The system showed results with accuracy around **96.53.**

The error measure FRR of the proposed system in terms of is given by

$$FRR = \frac{\text{Number of rejected genuine claims}}{\text{Total number of genuine accesses}} X\,100\,\% \qquad (8)$$

$$FRR = \frac{5}{144} X\,100 = 3.47\,\%$$

Efficiency = 96.53%
FRR = 3.47%

8. Conclusions

The rapid growth in the use of e-commerce applications requires reliable user identification for effective and secure access control. Biometrics is being used all over the globe and is undergoing constant development. Hand geometry has proved to be a reliable biometric. The proposed work shows how to utilize the shape of the hand to extract features using very simple algorithms.

The selected biometric modality is user-friendly and is only affected by illumination. Peg free environment is used. Individual is free to put their hand in any direction and in any position. The hand geometry must be subjected to rotation and normalization such that the fingers are erected having substantial gaps among them. We have extracted the invariant features from the hand consisting of five finger lengths, fifteen finger widths (three for each) and four spatial distances (which are the distances from the finger tips to a fixed reference point on each finger) with a total of 24 features. The hand based biometric system is experimented on a database of 480 images collected from 48 users. Three sample images from each user are used for verification purpose and samples for the training. The results of verification are obtained using the SVM classifier which gives the accuracy around 95.84% on the database.

8.1 Suggestions for Future work

The thesis has explored the geometrical features only. One study that remains to be taken up is the use of the contours of fingers by some polynomial function like spline function. If we consider the contours of all fingers together the problem arises with regard to ever varying gaps between the fingers. This makes the job of polynomial function difficult because of varying contours. One easy way is to consider each finger contour separately by fitting polynomial curves like spline functions.

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