An Efficient Hand Image Segmentation Algorithm for Hand Geometry based Biometrics Recognition System

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ABSTRACT
In most of the previous works on hand-based recognition methods, mostly, the significance was not given to the side of the hand, which is used in the model. The palm side of the hand is generally used because, it is very easy to capture using a simple scanning device and we can extract the shape based features as well as the palm print from the same image. Dorsum of hand (backside of hand or topside of hand) is the apposite side of the palm side of the hand. In this work, we highlight some of the advantages of using dorsum of hand for modeling a biometrics based human recognition system. Segmenting the hand image is the most important step in any hand geometry based recognition systems. We realized that the segmentation algorithm used for segmenting the palm side of the hand will not be suitable for segmenting the dorsum of hand. In this paper, we address a simple and fast method for segmenting the dorsum of hand image. The proposed method can be used in hand geometry based recognition algorithms which use the dorsum of hand as the input.

Keywords
Biometrics, Dorsum of Hand, Hand geometry, Human Recognition.

1. INTRODUCTION
Hand geometry is one of the biometrics used to find practical use across the real-world security related applications. A hand geometry based recognition system works by capturing the image of a hand to determine its geometry and metrics namely the finger length, width and other attributes. Hand image segmentation is an important step in any hand geometry based recognition system. Because, the accuracy of the identified feature will be detected using a segmented hand image and it is totally depend upon the quality and accuracy of the segmented hand image.

1.1 Palm Side of the Hand and Dorsum of Hand
There are two sides in a hand. One is well known as palm print side or simply palm side of the hand. The other side or opposite side of the palm side of the hand is refereed in a very common way as "back side" of the hand or "top side" of the hand. In this paper, we refer it as "Dorsum of Hand" since the word "Dorsum" is technically used in some literature to refer "back/top" of a body part.

Most of the earlier works [4] including our previous works [12] [13] address the way of using palm side of the hand to extract different features of the hand and use those features to design biometrics based human recognition systems.

Even some of the earlier works [3] the equipment they used for capturing the top side /dorsum of hand image, generally, capture the top view of the hand image and detect the different geometric features from it and use those features to design biometrics based human recognition systems.

1.2 Problem Specification
In a previous work [13], we address a fast and efficient threshold based segmentation algorithm for segmenting palm side of the hand image which was acquired from a scanning device. That algorithm gave excellent results for segmenting the scanned palm-side of the hand image. Because, the palm side of the image will be almost homogeneous. But the dorsum of hand image is not homogeneous due to the nature of different skin tones in different areas of the dorsum of hand. And most importantly, the area of the nails and the different knuckle print areas of hand will be distinguishably in different shade. Further, the difference in the shades of skin colors among different people is very much deviating from the difference of shade of palm side of the same people.

The above facts make the design of the segmentation algorithm little bit complex.

1.3.1 Advantages of using Dorsum of Hand Image
- Dorsum of hand is easy to capture using a simple device like an ordinary digital camera. And even consume lesser time than that of the scanning device which is generally used for acquiring palm side of the hand. So it will reduce the enrollment and verification time considerably.
- During the acquisition of Palm Print side of the image using a scanner, the Hand pressure will distort the image considerably and even make some portions to look very flat – but this will not be in the case of using Dorsum of Hand image.

- Since the dirt and sweat on the palm will spoil the clean surface of the scanner which is used for capturing the palm side of the hand. But in the case of, the device used for capturing dorsum of hand, the hand will not spoil the capturing device even at extremely dirty conditions. So the capturing device will not need frequent cleaning.
- Even there is a possibility of adding the skin color of the hand as an additional attribute while using dorsum of hand.
- During using the dorsum of hand, there is a possibility to find the absolute length of the by subtracting the length of the finger nails. It is not possible while using the palm side of the hand image.
- Dorsum of Hand will not be dirty than that of the palm side of the hand even in dirty work environment.

Since the blood most of the vessels and veins are very near at the surface of the dorsum of hand, there is a possibility of adding IR imaging technique to differentiate the real human hand from the fake imprints which will be used to attack the system. Even a sophisticated camera can be used to acquire both the normal as well as IR image.

1.3.2 Image segmentation

One of the most difficult tasks in image processing is segmentation process. Image segmentation is the process of subdividing the given image into its constituent parts or objects homogenous with respect to certain features (Gonzales and Woods, 1993). The segmentation process is the first and most important step in image analysis since its performance directly affects the performance of the subsequent processing steps in image analysis. Image Segmentation still remains as an unsolved problem in the general sense as it lacks a general mathematical theory. The two main difficulties of the segmentation problem are it's under constrained nature (LaValle and Hutchinson 1995) and the lack of definition of the "correct" segmentation (Horn, 1986). Thus determination of the correctness and of the consistency of the segmentation result of a given scene becomes feasible only in specific tasks, e.g., knowledge based and ground truth.

The following are some of the existing methods commonly used for segmenting images.

- Clustering Based Methods
- Histogram-Based Methods
- Region-Oriented Segmentation
- Graph Partitioning Methods
- Neural Network Based Methods

Since it is a complex pixel level operation, segmentation process will consume lot of time. Most of the existing methods will not be suitable for applications which will require real-time performance. And further, in our proposed system, the high resolution hand image will consume lot of time to get segmented if we use most sophisticated algorithm such as Region-Growing Methods and Graph Partitioning Methods. So, the fast methods such as Clustering Based Methods and the Histogram-Based Methods were used for segmenting hand images. So, in this paper, we will implement a Clustering Based Method as well as a Histogram-Based Method and will propose a simple way to attain ideal segmentation in the case of hand image segmentation. So the outcome will be a custom made algorithm for segmenting the images of Dorsum of Hand.

1.3.3 Clustering Based Methods

Clustering is an unsupervised way of data grouping using a given measures of similarity. Clustering algorithms attempt to organize unlabeled feature vectors into clusters or "natural groups" such as samples within a cluster are more similar to each other than to samples belonging to different clusters. Since there is no information given about the underlying data structure or the number of clusters, there is no single solution to clustering, neither is there a single similarity measure to differentiate all clusters, for this reason there is no theory, which describes clustering uniquely.

1.3.4 Histogram-Based Methods

Histogram-based methods are very efficient when compared to other image segmentation methods because they typically require only one pass through the pixels. In this technique, a histogram is computed from all of the pixels in the image, and the peaks and valleys in the histogram are used to locate the clusters in the image. Color or intensity can be used as the measure. A refinement of this technique is to recursively apply the histogram-seeking method to clusters in the image in order to divide them into smaller clusters. This is repeated with smaller and smaller clusters until no more clusters are formed. One disadvantage of the histogram-seeking method is that it may be difficult to identify significant peaks and valleys in the image. This may affect the quality and usefulness of the final solution.

2. THE HAND IMAGE SEGMENTATION ALGORITHMS

The Hand Geometry Images can be extracted from a hand image captured by the top mounted camera. Unlike other multi-biometrics systems, the user does not have to undergo the inconvenience of passing through multiple sensors. With this simple image acquisition, they can be captured completely from the complexity of verification system by using a top mounted single camera setup.

The hand image segmentation is the very important step in a hand based biometrics identification system. There will be more steps in a typical hand based biometric recognition system; but in this work, we are going to evaluate some of the existing segmentation algorithm as well as a proposed segmentation algorithm. So, for this, we will use up to the following steps of a typical Hand based recognition system.

1) Hand Image Preparation
2) Hand Image Preprocessing
3) Hand Image Segmentation

2.1 Hand Image Preparation

Initially the hand images are obtained from the user group and stored in the database. For that purpose, we used normal digital camera which is mounted in a special arrangement. The hands geometry samples were captured at 72 DPI resolutions.

During the time of enrolling the users and preparing the dataset, the users are asked to place the hand stretched as much as possible on a single guide line drawn on the black surface on which the camera is mounted. The Guideline was used only to place the middle finger of the hand. The hand images of the same person were taken three times in different time intervals (in our case, we took it in three consecutive weeks).

We used the actual data set which we captured as the training data set. During evaluating the algorithm, we synthetically added random noise with the detected attribute set to mimic the difference in accuracy over time and tried to identify the hand of the noisy feature in features extracted from the original data set. Figure 1 shows one such example of the image of dorsum of hand.

Figure 1. The Input Hand Image

2.2 Hand Image Preprocessing

In the preprocessing stage, the input hand image is preprocessed to adjust the contrast and brightness. Then the preprocessed image is filtered using median filter to remove "Salt and Pepper" noises. It reduces the blurring of edges. Further, some unwanted portions of the original images were automatically cropped, resulting in clear hand images of uniform size and background. The images were then scaled down to a suitable size, smaller than the original size for handling them with better performance in terms of speed. Figure 2 shows the cropped, region of interest (ROI) hand image.

Figure 2. The ROI of Input Hand Image

2.3 Hand Image Segmentation

For the purpose of extracting the geometrical features of the hand, we have to do a binary segmentation of the image to distinguish the hand only area from its background. For this purpose, in our earlier work [12] we addressed a new simple and very fast algorithm for hand image segmentation using filtering, edge detection and region labeling techniques [12] [13]. But the above said algorithm was not suitable for segmenting the image of dorsum of hand. The reasons are:

i) The palm side of the image will be almost homogeneous. But the dorsum of hand image is not homogeneous due to the nature of different skin tones in different areas of the dorsum of hand.

ii) Most importantly, the area of the nails and the different knuckle print areas of hand will be distinguishably in different shade.

iii) Further, the difference in the shades of skin colors among different people is very much deviating from the difference of shade of palm side of the same people.

The above facts make the design of the segmentation algorithm little bit complex.

Figure 3. The Segmented Hand Image

2.4 Clustering of Pixels using RGB Values

First, an colour hand image is taken as an input. The input image is in the form of pixels and is transformed into a RGB feature space. Next similar data points, i.e. the points which have approximately similar color, are grouped together using any clustering method. A clustering method such as k-means clustering is used to form clusters as shown in the figure 4. The distances are calculated using Mahalanobis or Euclidean distant.

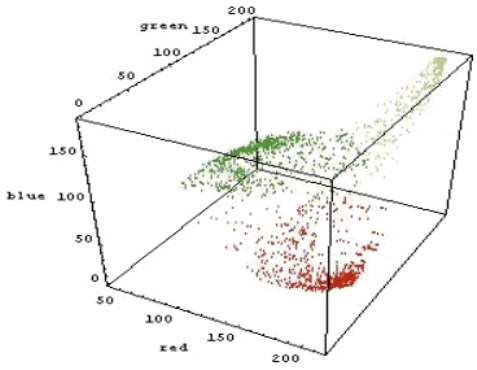

Figure 4 : The Pixels in Colour Space

The above figure shows how the data points are clustered in the 3D RGB space. As one can see all similar colours are grouped together to form a cluster. The data points with minimum Mahalanobis distance or Euclidean distance are grouped together to form the clusters.

Let us assume a colour image as a set of n colour pixels, then we can represent it as follows :

$I = \{ (r_1,g_1,b_1), (r_2,g_2,b_2), \ldots\ldots (r_n,g_n,b_n) \}$

So, using any clustering algorithms, we can cluster this set of n pixel values. In this hand image segmentation, we have to segment the background and the hand image. So we have to segment the set of pixels in to two groups.

2.4.1 The General form of k-mean Clustering

K-Means Clustering is an iterative technique that is used to partition an image into K clusters. The basic algorithm is:

1. Select K cluster centers, either randomly or based on some heuristic

2. Assign each pixel in the image to the cluster that minimizes the variance between the pixel and the cluster center

3. Re-compute the cluster centers by averaging all of the pixels in the cluster

4. Repeat steps 2 and 3 until convergence is attained (e.g. no pixels change clusters)

In this case, variance is the squared or absolute difference between a pixel and a cluster center. The difference is typically based on pixel color, intensity, texture, and location, or a weighted combination of these factors. K can be selected manually, randomly, or by a heuristic.

This algorithm is guaranteed to converge, but it may not return the optimal solution. The quality of the solution depends on the initial set of clusters and the value of K.

Euclidean Distance

Euclidean Distance = $\sqrt{((x1 - x2)^2 + (y1 - y2)^2)}$ (1)

Where (x1, y1) & (x2, y2) are two pixel points or two data points.

In most cases when people mention about distance, they refer to Euclidean distance. Euclidean distance or simply 'distance' examines the root of square differences between coordinates of a pair of objects.

The weakness of this kind of distance metrics were discussed in several works. Even though they are weak in some aspect, they are very simple and direct methods in implementation point of view.

2.5 The proposed Segmentation Method

We can represent the three layer of the color image (Red, Green and Blue layers) seperately as follows :

The image I ={ R, G, B }

Each layer R, G and B can be treated as three separate gray image and we can apply image processing techniques on them.

The median filter is an effective method that can suppress isolated noise without blurring sharp edges. Specifically, the median filter replaces a pixel by the median of all pixels in the neighborhood:

$$y[m,n] = median\{x[i,j], (i,j) \in w\} \quad (2)$$

Where ω represents a neighborhood centered around location (m,n) in the image.

We applied median filter separately on the three layers of the hand image and it will give the new image,

The median filtered Image Im = { Rm, Gm, Bm }

After this operation, each layer scaled differently by multiplied each value by a different factor.

Since there are 256 levels in each layer, we can calculate these multiplication factors as follows:

$f_r = 1$, $f_g = 256/2$, $f_b = 256$,

If we multiply each layer values with these factors, then all the three layers will be scaled.

Im = { Rm, Gm, Bm }

So the resultant image layers scaled differently can be represented as follows:

$I_S = \{Rm * f_r , Gm * f_g , Bm * f_b \}$

Since the pixel values are scaled differently, the distance metric used in clustering algorithm leads to better segments.

3 IMPLEMENTATION AND RESULTS

We have tested the algorithms and the hand recognition system on a normal desk top computer. To evaluate the performance, noise was synthetically added with the detected geometry based training attributes.

The following figure 5 shows the difference in performance of the normally clustered pixels and the differently scaled pixels using k-mean clustering algorithm. The images used to show the difference in performance were some what poorly captured ones. Due to bad camera settings (or the texture of black cloth materiel used in the background), the lighting in the background is not uniform and it is very bad near the thumb of the hand image. This uneven lighting condition makes the segmentation as a challenging one. The normal method was not able to identify the correct segments. But the proposed method was able to identify good segments.

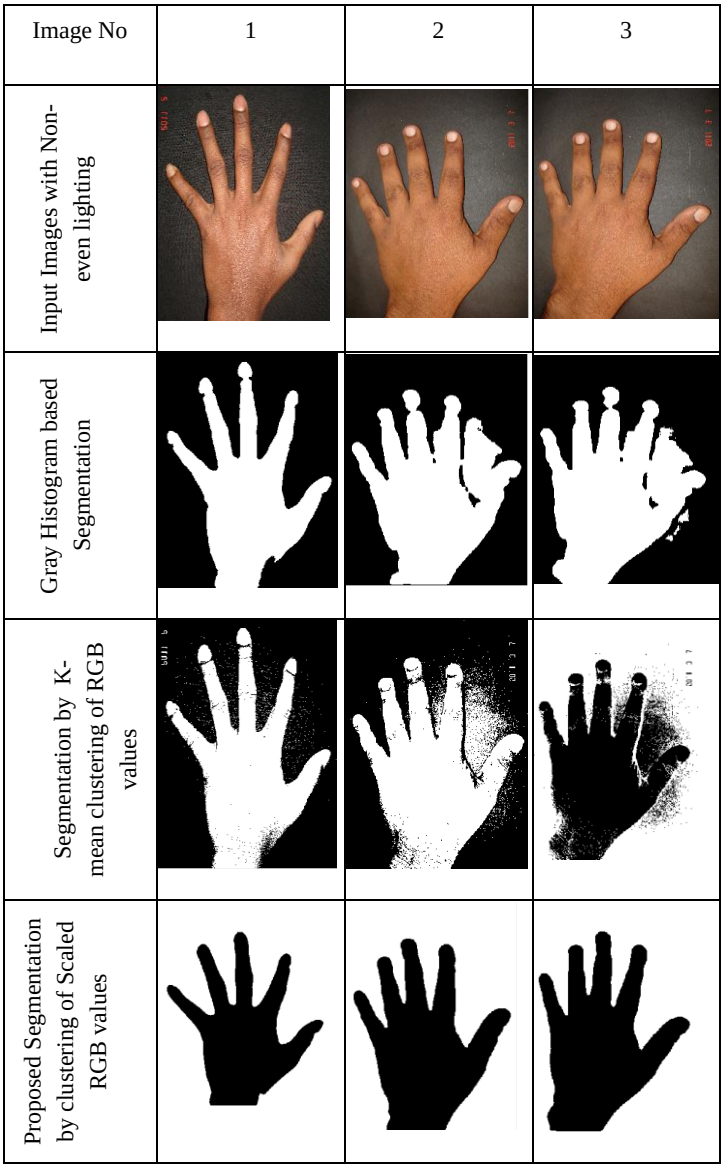

Figure 5. Results of different Segmentation Methods

4. CONCLUSION

The objective of this work was evaluating the suitability of some of the commonly used segmentation algorithm for the application of hand geometry based recognition system which will use the image of dorsum of hand for extracting features. We have shown that the frequently used segmentation algorithms were not suitable for segmenting the image of the dorsum of hand. We designed a simple algorithm by modifying the normal k-mean Clustering of Pixels using RGB Values. Before clustering the RGB pixels, we separately applied a median filter operation in the three layers of image and then scaled the resultant R, G and B layers of the image with different factors. The reason for good segmentation is, this operation on the RGB layers leads to a better segmentation by overcoming the weakness in the distance metric part of the clustering algorithm.

The arrived segmented images were very ideal and much suitable for using them in any hand geometry based recognition system.

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