

**DOKUZ EYLÜL UNIVERSITY**  
**GRADUATE SCHOOL OF NATURAL AND APPLIED**  
**SCIENCES**

**CLASSIFICATION OF HAND IMAGES USING**  
**GEOMETRIC FEATURES**

by  
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**February, 2013**  
**İZMİR**

# **CLASSIFICATION OF HAND IMAGES USING GEOMETRIC FEATURES**

**A Thesis Submitted to the  
Graduate School of Natural and Applied Sciences of Dokuz Eylül University  
In Partial Fulfillment of the Requirements for the Degree of Master of Science  
in Electrical and Electronics Engineering**

**by  
Neslihan Karakurt**

**February, 2013  
İZMİR**


**M. Sc THESIS EXAMINATION RESULT FORM**

We have read the thesis entitled “**CLASSIFICATION OF HAND IMAGES USING GEOMETRIC FEATURES**” completed by **NESLIHAN KARAKURT** under supervision of **ASST. PROF. DR. METEHAN MAKİNACI** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

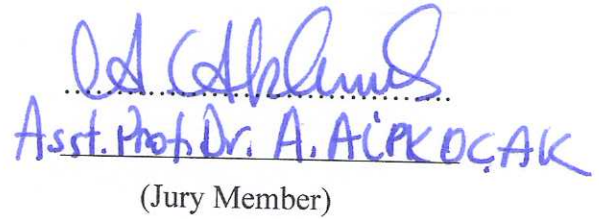


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Neslihan KARAKURT

# CLASSIFICATION OF HAND IMAGES USING GEOMETRIC FEATURES

## ABSTRACT

Personal identification and verification systems are very important for high security and ease of usage in these days. These systems are hand recognition, fingerprint recognition, iris recognition; face recognition which uses biometrics traits. These are the systems with which the entry/ exit of personnel or students in and out of the factories, firms, hospitals and schools are controlled, with which the number of working days and hours are found, in short with which all the information can be obtained.

In this study, hand recognition system which uses geometric features (finger length width, area size of the palm) and various classification methods establishing how to work with minimum error rate, have been examined. We have formed a hand database. This database includes a total of three-hundred images by taking five images per person. The most suitable image processing methods were used for a good feature extraction process. Then, for the feature extraction process, classification methods were implemented to the results obtained by image processing.

Two classification methods are used in this project. They are k-Nearest Neighbor Algorithm and Linear Discriminant Analysis. The success rate of k-NN Method is 97.0 percent; the success rate of Linear Discriminant Analysis is 97.7 percent for the database containing 16 features with 300 hand images obtained from 60 people.

The results were obtained by different methods and algorithm, and a table showing the minimum error rates according to the method used, was prepared. Results were compared. The best method for hand recognition system was decided.

**Keywords:** Image processing, k-NN method, feature extraction, hand images, Linear Discriminant Analysis.

# GEOMETRİK ÖZNETELİKLER KULLANARAK EL GÖRÜNTÜLERİNİN SINIFLANDIRILMASI

## ÖZ

Kişi tanıma ve doğrulama sistemleri güvenlik ve kullanım kolaylıkları bakımından çok önemlidir. Bu sistemler el tanıma, parmakizi tanıma, iris tanıma, yüz tanıma gibi biometric sistemlerin kullanıldığı sistemlerdir. Fabrikalarda firmalarda, hastanelerde veya okullarda çalışanların veya öğrencilerin giriş çıkışlarının kontrol edildiği, çalışma günlerinin ve saatlerinin sayısının çıkarıldığı kısacası tüm bilgilerin otomatik düzenlenebildiği sistemlerdir.

Bu çalışmamızda, geometrik özniteliklerle çeşitli sınıflandırma yöntemlerinin kullanıldığı, minimum hata ile sistemin nasıl işleyeceğine dair çalışmalar yapılan el tanıma sistemleri üzerine çalışılmıştır. Bize ait olan düzeneğimizle el veritabanı oluşturulmuştur. Bu veritabanı herbir insandan 5 görüntü alınarak toplamda 300 adet görüntü içermektedir. Bu görüntülere iyi bir öznitelik çıkarma işlemi için en uygun görüntü işleme yöntemleri kullanılmıştır. Öznitelik çıkarma işlemi için yapılan görüntü işlemeyle elde edilen sonuçlar sonrasında bulunan veri tabanına sınıflandırma yöntemleri uygulanmıştır.

Bu projede k-NN yöntemi ve Doğrusal Ayırma Analizi olmak üzere 2 adet sınıflandırma yöntemi kullanılmıştır. 60 kişiden alınan 300 adet el görüntüsü ile 16 öznitelige sahip veri tabanı için k-NN yöntemiyle elde edilen başarı yüzde 97,00 , Doğrusal Ayırma Analiziyle elde edilen başarı yüzde 97,7'dir.

Farklı yöntem ve algoritmalarla sonuçlar elde edilmiş ve kullanılan yöntemlere göre minimum hataları gösteren tablolar yapılmıştır. Sonuçlar karşılaştırılmıştır. El tanıma sistemi için en iyi yöntemin hangisi olduğuna karar verilmiştir.

**Anahtar sözcükler:** Görüntü işleme, k-NN yöntemi, öznitelik çıkarma, el görüntüleri, doğrusal ayırtaç analizi.

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## CHAPTER ONE

### INTRODUCTION

#### 1.1 Biometric Systems

Biometrics is a general term used for the automated, computer-controlled systems developed for the identification by recognizing the physical and behavioral features of the user. Traditional method to prove who you are to a system is to use passwords and PIN codes. But these lost their reliability with the deciphering of the encryption algorithms. Biometric systems basically work by recognizing a physical or behavioral feature of an individual which is unique to him/her, cannot be changed or can be distinguished from the others.

Recently, interest in these biometric systems increased. These systems provide high security access control when entering through the door without the credential which could be stolen.

There are a lot of biometric systems. These systems, their advantages and disadvantages are given below.

##### *1.1.1 Fingerprint Recognition*

Fingerprint recognition is one of the oldest systems. However it is the most commonly used system. Devices used in these systems are small and decorative. There are various products as trademark, model, price related to the fingerprint recognition systems.

Mode of operation: During the fingerprint identification, product takes an image of your finger and saves it with code number in its memory. When you enter this code, it wants you to introduce the read finger again.

Disadvantages: If finger is dirty or fingerprint is spoiled due to extreme friction, the product doesn't work correctly. The products which you can find easily in markets generally do not have enough speed and capacity. They aren't hygienic due to others touching it. Each device works with a single package.

### ***1.1.2 Iris and Retina Recognition***

This system started to be used in 1930s. Although it is an old system, it is used commonly.

Line, color and spot which exist on iris is essential for Iris Recognition, shape of slim capillary which is behind the retina is essential for Retina Recognition.

Mode of operation : A person must look at the camera for recognition and identification for these systems. Standard CCD is used for iris recognition however, low density and uninterrupted light source is used to take images of capillary for retina recognition.

Disadvantages: Verification process takes a long time and it is an expensive system. Mode of operation of these systems is the same as fingerprint recognition systems.

Therefore, for verification and identification, what is important is the angle the person looks from while the image is taken. Both of them can be from the same angle. When contact lenses are used, this system can be misleading.

### ***1.1.3 Face Recognition***

It is recognized from the distance of eyes, width of nose, cheekbone, jaw line etc. which are the general features of people's faces.

Mode of operation: Face images are obtained with the help of standard camera. If the person wants his/her face to be read, he/she should look at the camera from the same angle and wait for the system identification process.

Disadvantages: Identification rate and speed which are the most important disadvantages of face recognition are low and slow. Manufacturers cannot give a 100% guarantee of recognition, so currently this system isn't often used.

#### ***1.1.4 Hand Recognition***

As it can be understood from its name, hand geometry reading technology is based on the principle of the measurability of the physical characteristics of the users such as hand and fingers, in three dimensions. Hand geometry reading devices are a lot more easily integrated with other systems and processes.

Mode of operation: For the hand recognition, geometric features such as finger width, length and surface are used. They are unique and unchanging features of a person.

Disadvantages: As it uses geometric features, it is copied easily. But this problem is solved by infrared camera and encryption methods. In these days, companies generally use hand recognition system with an infrared camera.

There are seven factors defined by Jain, Bolle, and Pankanti (2002) that determine the suitability of a physical or a behavioral trait to be used in a biometric application.

Table 1.1 shows physiological and behavioral biometric techniques based on seven parameters.

Table 1.1 Comparison of biometric technologies

Biometrics	Universality	Uniqueness	Permanence	Collectability	Performance	Acceptability	Circumvention
DNA	High	High	High	Low	High	Low	Low
Ear	Medium	Medium	High	Medium	Medium	High	Medium
Thermogram	High	High	Low	High	Medium	High	Low
Fingerprint	Medium	High	High	Medium	High	Medium	Medium
Palmprint	Medium	High	High	Medium	High	Medium	Medium
Retina	High	High	Medium	Low	High	Low	Low
Hand geometry	Medium	Medium	Medium	High	Medium	Medium	Medium
Iris	High	High	High	Medium	High	Low	Low
Face	High	Low	Medium	High	Low	High	High
Gait	Medium	Low	Low	High	Low	High	Medium
Signature	Low	Low	Low	High	Low	High	High
Voice	Medium	Low	Low	Medium	Low	High	High
Keystroke	Low	Low	Low	Medium	Low	Medium	Medium

Nowadays, hand recognition technology is used with a device that is called Handkey (Fig. 1.1) in security and control systems. Therefore this system is preferred instead of card based passing system used for staff entry/exit.



Figure 1.1 Handkey

## 1.2 Outline of the Thesis

The thesis presented here aims at the following aspects. Respectively, the process takes place as shown below.

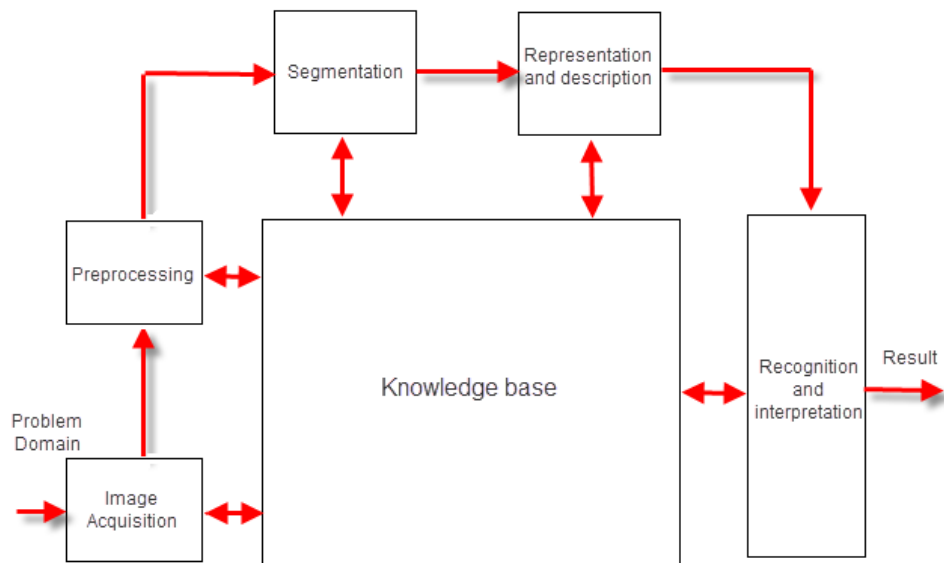


Figure 1.2 Recognition system process

According to Figure 1.2, firstly, system domain is given to software sequence for processing. When domain is taken, these processes take place with the stages below.

- Reading image (format “.JPG”)
  - Cropping to 240x320 pixels.
  - RGB values found in image for excluding fastener from image.
- } Image Acquisition
- Converting image to gray level.
  - Find suitable threshold at gray level for this database.
  - Edges of hand images found with Canny Edge Detection Method.
  - After edge detection, some noise eliminations.
- } Image Processing
- After all these process are done, hand images are available for a feature extraction.
  - Find hand features.
- } Feature Extraction And Class.

- Hand features are used for classification.

Generally, hand recognition system process is shown as below (Figure 1.3).

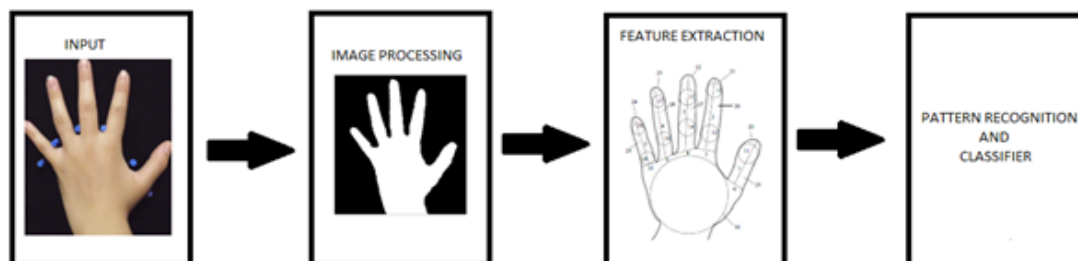


Figure 1.3 Hand Recognition Systems

### 1.3 Thesis Organization

This thesis presents hand recognition system of identification/verification systems. Chapter 2 includes how to preprocessing and segmentation of dataset for images. Chapter 3 includes used image processing methods and results. Feature extraction and used features are explained in Chapter 4. Then Chapter 5 discusses classification methods developed in this thesis. Chapter 6 concludes our study and in Chapter 7 future studies are presented.

## **CHAPTER TWO**

### **DATASET & SEGMENTATION**

#### **2.1 Dataset**

In this study, the database was obtained by taking five images per person from sixty people, a total of three hundred images by a CCD camera (Figure 2.1). Some properties of the camera are given as below.

\*Nikon Coolpix L20

\*10 megapixel resolution

\*D-Lighting (The camera own flash was used for lighting)

\*Focus: 136 mm

Format of the images is JPEG. It is a very efficient compressed 24 bit bitmap format.

For this science communication, the color spaces are RGB. The RGB color model contains the red, green, and blue colors. This model is formed with the combination of these colors.

A wood board was made for image acquisition set up. Hand images are obtained with the help of this contrivance. There is a hole for putting the standard camera on wood board. The ground is covered with black fabric.

Black background and blue fastener are used in this project. The reason of using a black background is that when hand color and black background are compared, inevitably, the hands have much lighter color than black background. So background and hands can be separated easily because of pixel difference.

However, these images have blue color fastener. Blue fasteners allow immobilizing hand images. With this method, the fingers are prevented from sticking together.

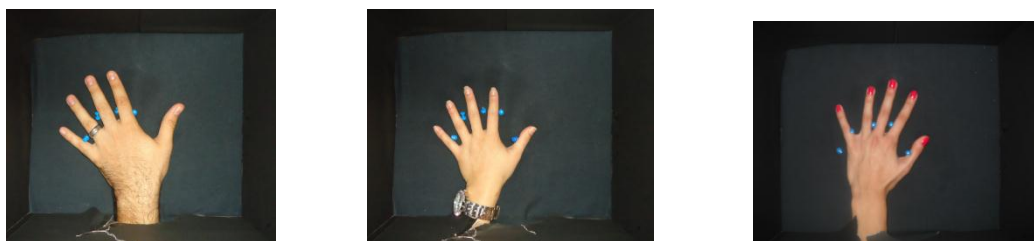


Figure 2.1 Hand images with accessories.

## 2.2 Segmentation

Autonomous segmentation is one of the most difficult tasks in digital image processing.

In this work, segmentation of the hand is to extract edges from the images. Data created by segmentation gives each all the extremity points in the region. Hands are light color. So they are separated from background easily. Results are shown in Figure 2.2 as below.

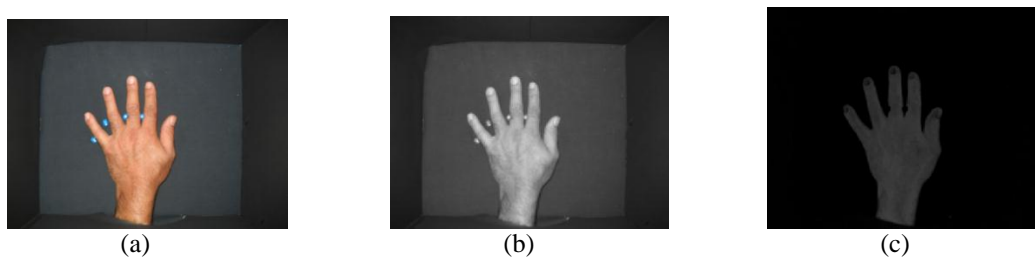


Figure 2.2 (a) Resized image , (b) Converted to graylevel, (c) Seperated from blue fastener

## CHAPTER THREE

### IMAGE PROCESSING

#### 3.1 Used Digital Image Processing Methods

“In imaging science, image processing is any form of signal processing for which the input is an image, such as a imagegraph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image.” (T. Acharya and A. K. Ray, 2006).

Digital image processing includes various methods which are used for changing an image and properties. The most basic level image processing is physically changing pixel’s values.

Different image processing methods can be analyzed separately from a lot of classes. There are different algorithms for different problems and types.

In this thesis, image processing methods are used explained respectively which methods are used and why they are used as stated below.

##### *3.1.1 Edge Detection*

Edge detection is a very important area in the field of image processing and pattern recognition. Edges effectuate the outer frame or extremity which separates the background from the object. Edge detection is the basic of image processing.

To illustrate the importance of edge detection, the following one-dimensional signal is given.

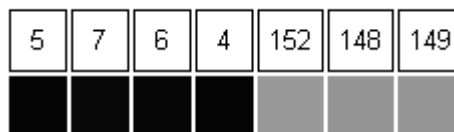


Figure 3.1 Difference of pixels

In Figure 3.1, difference is distinctive between 4<sup>th</sup> and 5<sup>th</sup> pixels. This distinction creates the edge.

In this work, firstly, the threshold value is chosen for edge detection. It is easy because background and hand palm are different from each other in terms of pixel value. Hand palm is easily separated from background.

### 3.1.1.1 Canny Edge Detection

This method is a multi-step edge detection procedure by Canny. The purpose of the following method is to detect edges with noise suppressed at the same time. “The method uses two thresholds, to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is therefore less likely than the others to be fooled by noise, and more likely to detect true weak edges.” (Canny John, 1986) This method is the most commonly used one and how it works are given below.

Firstly, image is filtered with the first derivative of Gaussian function for reasons such as good edge determination and good edge location. After some noise in image is eliminated, canny operator is applied to the filtered image.

After canny detection methods are applied, the images which are taken from different people are shown as below (Figure 3.2).

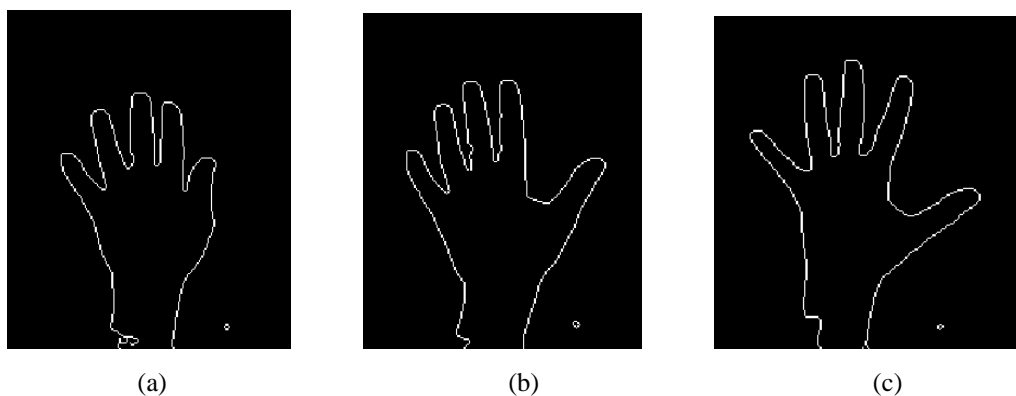


Figure 3.2 (a), (b), (c) Canny operator is applied to the images

### 3.1.1.2 Sobel Edge Operator

Sobel Edge Detector is the most known among image processing algorithms. Two convolution kernels are used in this algorithm. One of them finds horizontal edges, other finds vertical edges. These kernels are necessary for determining section which changes the intensity in image. There are two sobel operators which are shown as below.

$$g_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}, \quad g_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

When sobel operator is applied to hand images, obtained results are shown in Figure 3.3 (a).

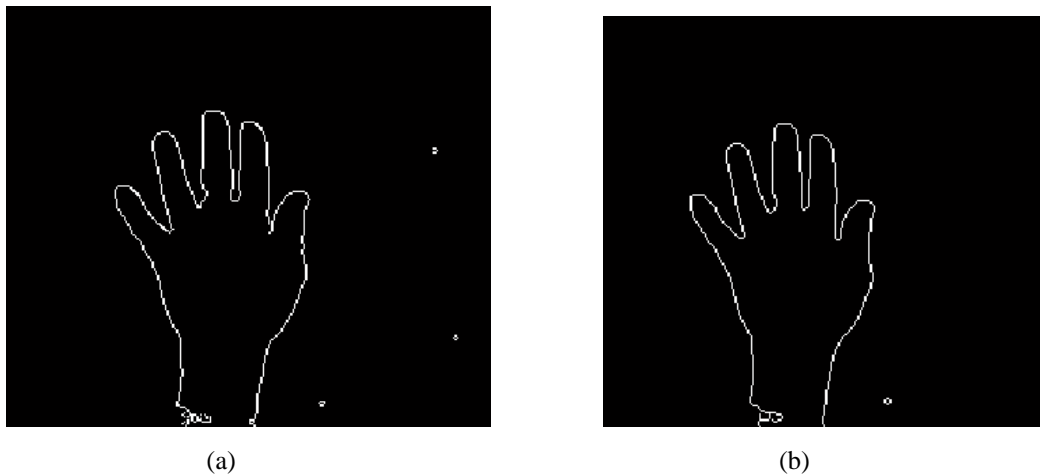


Figure 3.3 (a) Sobel operator applied to image, (b) Canny edge detection the image applied to the image

As shown in Figure 3.3 (a) and Figure 3.3 (b) to the images sobel operator and canny edge detection are applied.

### 3.1.1.3 Prewitt Method

Prewitt Operator is similar to the Sobel, with different mask coefficients:

$$y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$$

$$\text{Edge Magnitude} = \sqrt{x^2 + y^2} \quad \text{Edge Direction} = \tan^{-1} \left[ \frac{y}{x} \right]$$

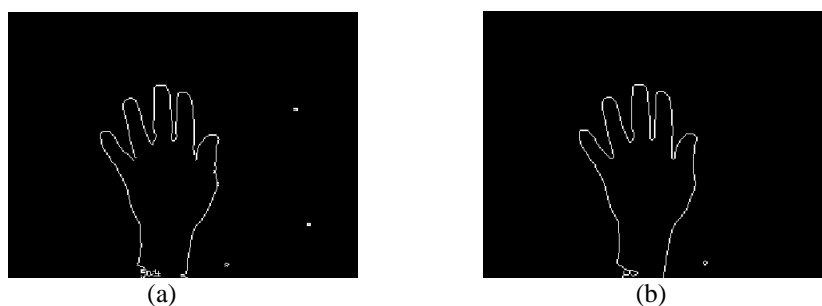


Figure 3.4 (a) Prewitt Method applied to the image, (b) Canny Edge Detection applied to the image

There is an image to which Prewitt Method is applied in Figure 3.4. According to the image, quantity of noise increased with Prewitt Method. The other picture is applied canny edge detector image. As seen in these pictures, the image which is applied canny detection is more successful.

Images obtained when different methods such as Sobel Operator, Prewitt, Canny Detection are applied, are shown as below. (Figure 3.5)

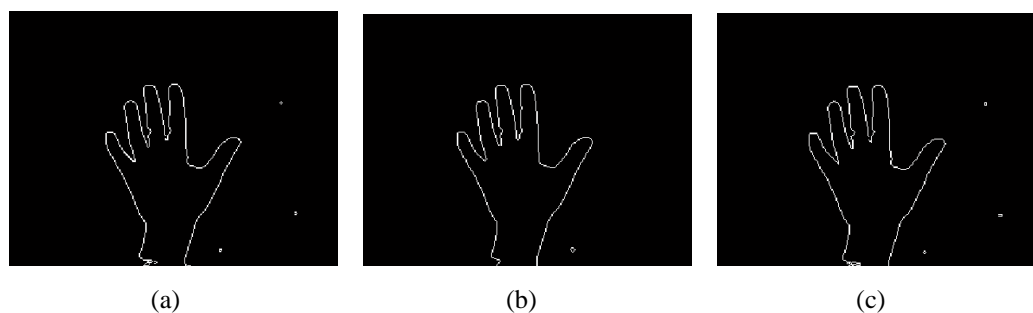


Figure 3.5 (a) Sobel operator , (b) Canny detection (c) Prewitt method

In this case, optimal edge detection method is Canny Edge Detection Method.

### 3.2 Image Noise Elimination

After finding edges of the hand images and before finding the coordinates of these pixels, the image has to completely be simplified. Artifacts in the image which are created because of noise can be eliminated easily. All the small connected components corresponding to artifacts in the image are removed. Connected components with small pixel number are removed from the image with a threshold number. Therefore, the little artifacts that hinder the simplification are eliminated. When the algorithm is implemented, the results are shown on Figure 3.6.

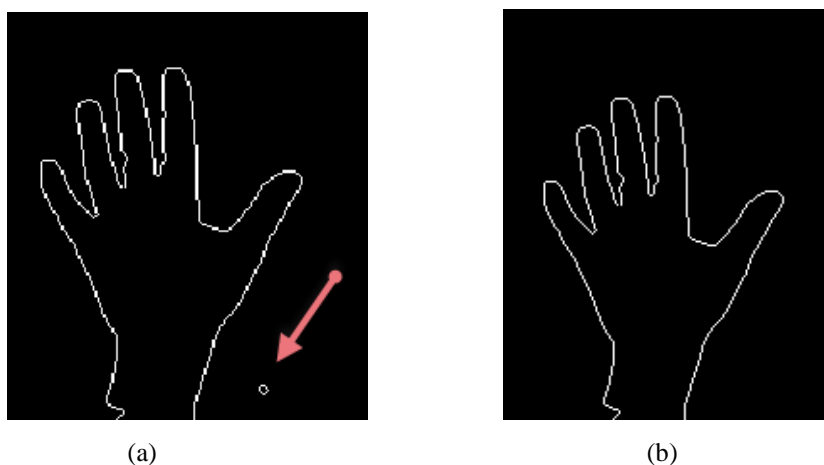


Figure 3.6 (a) Image with noise, (b) Noise eliminated image

### 3.3 Coordinate Calculation

Before passing on to the feature extraction process, a method was developed in order to calculate the coordinates of the edges whose extremities were calculated.

Firstly, image is rotated 180 degrees. (Figure 3.7) Then, starting from the corner (0, 0) of the image, the method investigates the pixel values one by one to find the address of the edge pixels respectively. It is found at the starting  $x=0$ ,  $y=0$  points and wrist with the collection of pixels in one of hand. The purpose of investigating pixels one by one is to ensure independence from rotation. This algorithm uses connected component method.



Figure 3.7 Rotated image

While finding the coordinates, the problem of pixel losses in some points occurred. In case the pixels whose connected components were looked into didn't have a neighbor, scanning range of 3 pixels was given. Here 3 is a threshold value. It is understood that if there is no neighboring pixels in 3 pixel ranges, the extremity was farther. After neighbors of each pixel extract with 8 connectivity, 3 pixel ranges on left side are checked. When edge pixel is found, to find coordinate algorithm continue from here. This problem is shown in Figure 3.8.

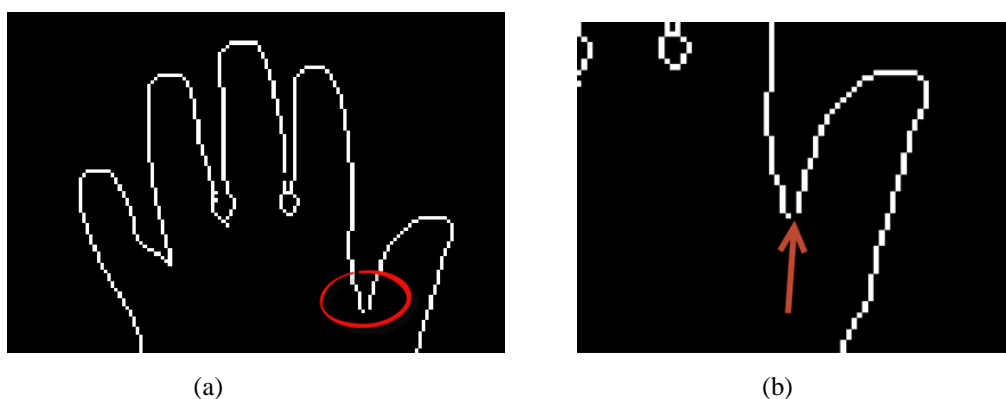


Figure 3.8 (a) Loss of pixels in an image, (b) Zoomed image

After all image processes are finished, now it's time to find the features to be used for the classification process.

### **3.4 Image Processing Results**

In this section, some processes related to image processing were performed. All of these are the steps taken to ease the feature extraction in the future. If obtained results with image processing are the best, feature extraction and classification are good and error is minimum and this result is perfect for recognition systems. Because; the purpose of the recognition systems is to achieve minimum error and correct classification.

## CHAPTER FOUR

### FEATURE EXTRACTION

#### 4.1 Description

Feature means property of one object. It is used to distinguish that object from others. The works which are done for finding features are called 'feature extraction'. Feature extraction is the most important step in recognition system. These values must be correct. Otherwise, classification process fails.

Our database includes sixteen features of hand images. They are physical properties from each person's hand, such as length, width, surface area.

#### 4.2 Feature Extraction and Used Method

A graphics which shows the distance to the center of gravity the fingertips (a, c, e, g, i points) and points between fingers (b, d, f, h) of the hands, are obtained and shown in Figure 4.1. Center of gravity the extremity pixels were taken as a reference point. From the center of gravity, the distance of the pixels whose coordinates were extracted, to the pixel address (y coordinate) in the increasing direction was calculated.

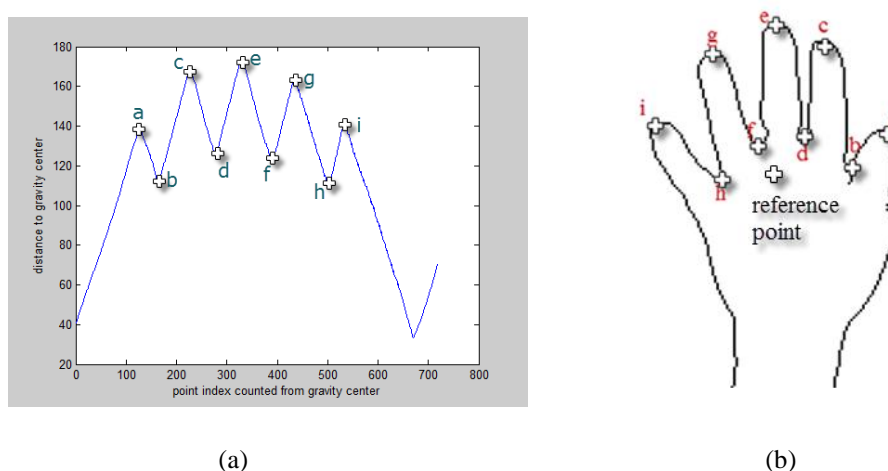


Figure 4.1 (a) Distance to gravity center , (b) A hand contour with marked extremities

### 4.3 Hand Features

Sixteen different features are extracted from each image. They are shown in Figure 4.2.

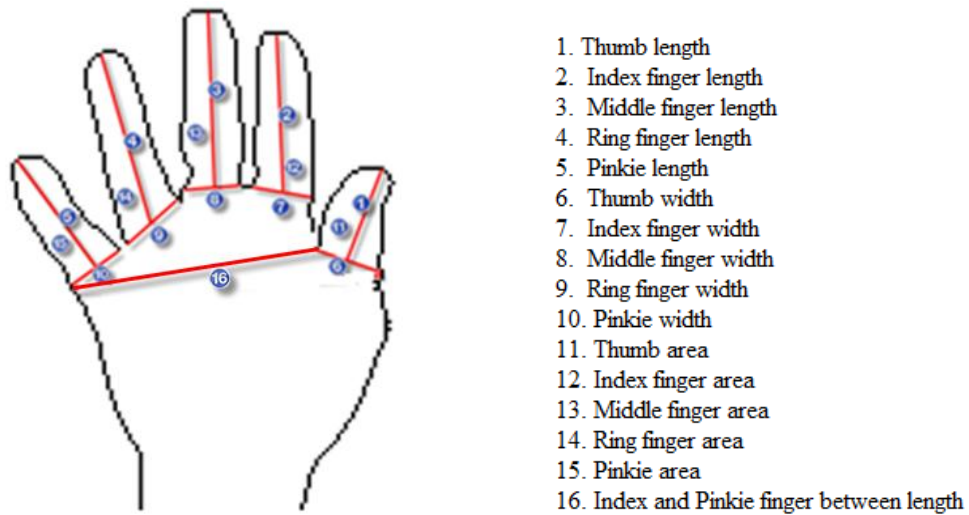


Figure 4.2 Features of hand images

#### 4.3.1 Width of Fingers

Firstly, distances between d and f points, f and h points are calculated. They are width of middle and ring fingers. Calculating the width is easy, because the points between the fingers are known. Then the width of thumb, index and pinkie fingers should be calculated.

After the necessary algorithms were implemented, pixels corresponding to these middle finger, thumb and pinkie finger were extracted. These are x, y and z points as shown in Figure 4.3 below. In order to find these points, an algorithm as follows was used. h length is calculated from the endpoints of fingers, which were previously found, as shown in the figure. Pixel value on the outer part of the finger, which corresponds to t length, which is in the same distance with this h length, is calculated. This triangle on the finger can be considered as an isosceles triangle. After this point is extracted, the calculations of the width of fingers are like previous ones. Width for these three fingers is calculated like this.

After these points are extracted, finding the width of the fingers have become as easy as calculating the widths of the middle and ring fingers.

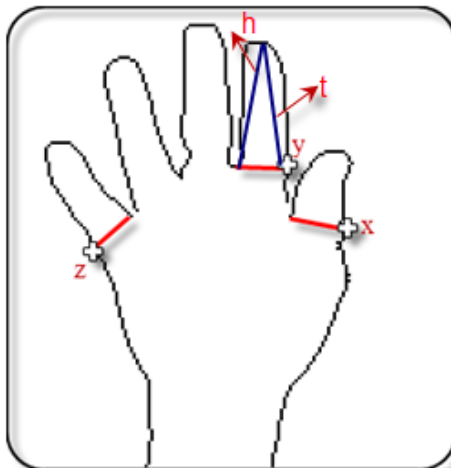


Figure 4.3 Need to find points

After these studies, all finger widths have been found.

#### 4.3.2 Length of Fingers

After finger widths are extracted, finger length, which is a person's physical property, is found easily. The distance from the coordinates of the edges of the fingers, which were found before, to the coordinate of the middle point of the finger width, gives us the length of the finger. It is shown in Figure 4.4. The algorithm is

$$[\text{Length } (y)]^2 = z^2 - x^2$$

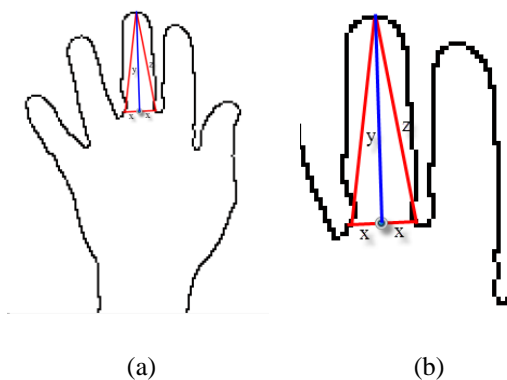


Figure 4.4 (a) Finger length, (b) Zoomed image

### 4.3.3 Area of Fingers

In order to calculate find the area a finger covers, our image converted into black and white format as shown in figure 4.5. First, in this image, the extremities belonging to only one finger were converted into a different pixel value. The other pixel values were made 0. After these processes, as the pixels covering the extremities of this finger constitute a whole, the areas of the fingers were extracted easily.

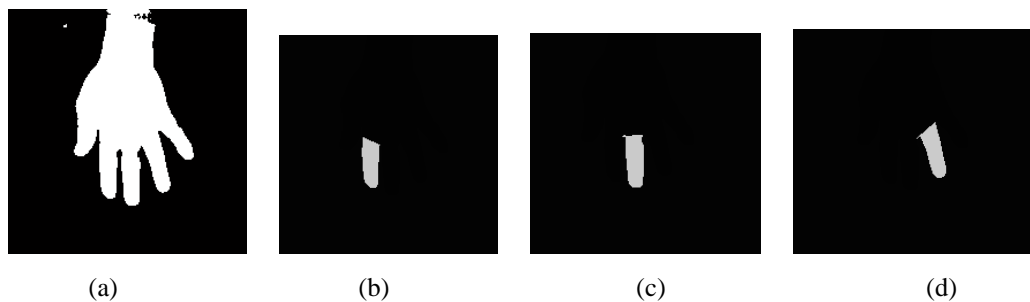


Figure 4.5 (a) hand image, (b) index finger, (c) middle finger, (d) ring finger

In these images, all pixels are counted. Each image shows one different finger. Total pixel number gives us the area of fingers.

### 4.3.4 Hand Width

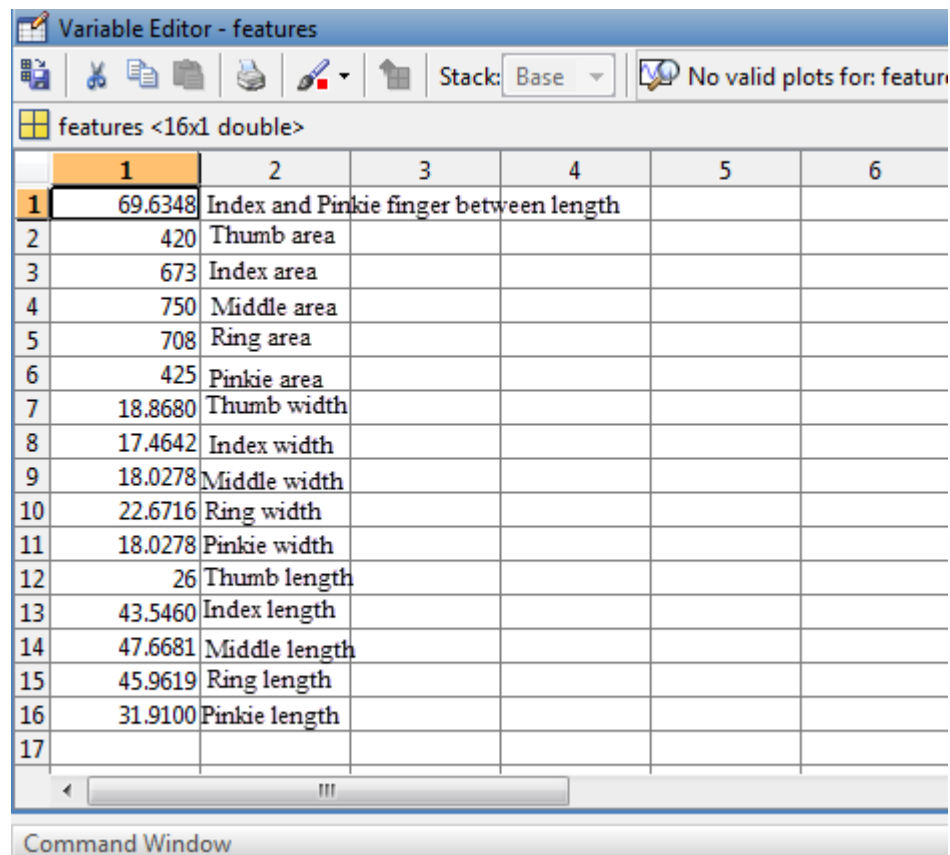
Hand width has been calculated by measuring the distance between the outer side of the little finger and the outer side of the index finger. Calculating hand width is easy, but it is an elusive parameter. Because it depends on how you put your hand on image platform. Therefore this parameter sometimes can be good feature, sometimes bad feature. The reason why it is considered as an unreliable parameter is given by the feature analysis, which is done in the following section. Statistical analysis gives low F values for this feature.

## 4.4 Feature Extraction Results

After the method used and the mathematical calculations, 16 features for each of the hand image were calculated. The features were stored in a matrix. Seventeenth column includes class name, such as 1<sup>st</sup>, 2<sup>nd</sup> classes.

This column is used as a label in the classification process. The database with class number is saved with '.mat' extension.

The features of each hand are written as row and saved under 'features' name. They are given as row to discernible in Figure 4.6 respectively as below.



	1	2	3	4	5	6
1	69.6348	Index and Pinkie finger between length				
2	420	Thumb area				
3	673	Index area				
4	750	Middle area				
5	708	Ring area				
6	425	Pinkie area				
7	18.8680	Thumb width				
8	17.4642	Index width				
9	18.0278	Middle width				
10	22.6716	Ring width				
11	18.0278	Pinkie width				
12	26	Thumb length				
13	43.5460	Index length				
14	47.6681	Middle length				
15	45.9619	Ring length				
16	31.9100	Pinkie length				
17						

Figure 4.6 Feature names and values of one hand.

When the features of all hand image samples are calculated, created matrix has number of row=300, number of column=16.

#### 4.5 Feature Analysis

The more successfully the feature analysis in a classification problem is made; the better will be the results of classification. For this reason, before initiating the classification process, some mathematical calculations are made on the features found.

't-test' is the most frequently used method in these calculations. The averages of two groups are compared with the t-test, and it is determined whether the difference between them is coincidental or statistically meaningful. As t distribution, which is also known as small sampling theory, enables studying with small samples, it provides great convenience for researchers. "t" test is an analysis method, which has been developed for testing the hypothesis related to whether there is a difference between independent two groups with regards to a variable under examination by benefiting from "t" distribution in cases that the sample sizes are small and standard deviations related to groundmass are unknown.

The method of t-test, intended to solve our problem, has been implemented on differences between two independent samples.

Some parameters in the Table 4.1 have been found after t-test, and an analysis of regression and differentiating between groups has been made according to these parameters.

Table 4.1 Mean, Std. Deviation of Feature Data

<b>Group Statistics</b>				
<b>V16</b>		<b>N</b>	<b>Mean</b>	<b>Std. Deviation</b>
V1	1	5	6.876.149	2.611
	60	5	655.609	31.109
V2	1	5	560.6	47.732
	60	5	329.8	131.125
V3	1	5	724.6	25.195
	60	5	203.6	214.469
V4	1	5	779.6	19.243
	60	5	472	106.583
V5	1	5	711	10.909
	60	5	438.6	115.704
V6	1	5	471.4	22.887
	60	5	264.6	63.382
V7	1	5	20.991	0.96
	60	5	12.561	30.277
V8	1	5	18.17	0.751
	60	5	15.99	1.798
V9	1	5	180.265	0.7446
	60	5	2.755.386	54.755
V10	1	5	2.136.583	1.369
	60	5	26.573	34.538
V11	1	5	19.54	20.493
	60	5	3.415.522	7.632
V12	1	5	333.821	2.651
	60	5	341.453	23.823
V13	1	5	45.496	0.9594
	60	5	20.501	10.733
V14	1	5	49.407	15.262
	60	5	32.87	71.397
V15	1	5	4.637.019	0.3627
	60	5	296.046	83.967
V16	1	5	3.120.789	0.72
	60	5	2.662.526	50.502

Attention should be paid on whether there is any variance difference between groups during the calculation of the t-test, with which two independent groups are compared.

For this reason, first the variances should be tested for equality before t-test calculations. One of these tests is Levene's test. The results of this test are illustrated in the Table 4.2 below.

Table 4.2 Levene's Test Results

<b>Independent Samples Test</b>		
<b>V16</b>	<b>F</b>	<b>Sig.</b>
V1	0.26	0.876
V2	2.413	0.159
V3	5.234	0.051
V4	4.345	0.071
V5	5.717	0.044
V6	2.372	0.162
V7	3.503	0.098
V8	2.663	0.141
V9	5.580	0.046
V10	1.664	0.233
V11	3.500	0.098
V12	0.170	0.691
V13	5.744	0.043
V14	3.982	0.081
V15	6.052	0.039
V16	2.515	0.151

According to this table the conclusion is that the variances of the ones with a significant critic value below 0.05 and the ones with a 'F' value exceeding a certain value are different. Based on these ideas, 1st and 12th features are not necessary for this recognition system. So the success rates in both cases are compared for each classifier by observing these two values and considering the features.

#### **4.6 Cross Validation, Leave One Out**

In this study, our dataset was divided with specific ratios as train data and test data. While performing this division process, Leave One Out algorithm, which is a cross validation method, was used. In the general sense of this algorithm, for the same dataset, the chosen object is left out every time. Therefore, while carrying out the classification, it is certain that the train and test data are different from each other.

The reason why this method is preferred is that we have enough data for training. Only one piece of data is selected for the test according to this method. Consequently from the database having 300 samples only 1 piece of data is allocated for the test, remaining 299 pieces are allocated for training. The number of pieces of data, which give correct results, shows the performance of the system.

The dataset prepared after all these methods are applied, was made available for the classification processes. This train and test data sets were used in the following classifications methods respectively, which is described below; k-Nearest-Neighbor Algorithm and Linear Discriminant Analysis.

## CHAPTER FIVE

### CLASSIFICATION

#### 5.1 Description

After feature extraction process, dataset has been prepared for classification. Theoretical background of used classification methods are explained as theoretical. Obtained features are used in classification methods and results are shown in this section.

The methods K-Nearest and Linear Discriminant Analysis have been used for classification. There are unsuccessful cases as well as cases with high success rate in the methods implemented. The mathematical illustrations of these in tables have been described in each classification method explanation. Mathematical descriptions of the parameters showing the classification results can be made as follows.

In order to measure the success of the model generated by the classification method, criteria such as:

- Accuracy
- Error rate

are used. At the same time the numbers of classes estimated correctly in each five classes are shown in table as well.

Accuracy= Number of samples classified correctly / Total number of samples

Error rate=1-Accuracy

##### ***5.1.1 k-Nearest-Neighbor Algorithm***

K-Nearest-Neighbor Algorithm is the simplest one of the classification method. “In pattern recognition, the k-nearest neighbor algorithm (k-NN) is a method for classifying objects based on closest training examples in the feature space.

k-NN is a type of instance-based learning, or lazy learning where the function is only approximated locally and all computation is deferred until classification”. (Ruiqin Chang, July 2011)

#### 5.1.1.1 Algorithm

“An object is classified by a majority vote of its neighbors. “k” is always a positive integer. The neighbors are taken from a set of objects for which the correct classification is known”. (K. S. Sujatha, G. M. Karthiga, B. Vinod, 2012) There is a value as ‘k’ in method. This value means number of closest neighbors according to distance method. By the way, new feature’s class is which relatively depends on ‘k’ neighbors old features’. Based on this, “k” must be odd number.

#### 5.1.1.2 k-NN Tests

After features are obtained, firstly, k-NN method is used for classification in our system. After the features are found, Leave One Out-Cross Validation Method used for testing and training data can be selected from our database.

While using k-NN method, some parameters such as calculating distance and number of neighbors are used. There are a few methods to calculate distance. Firstly, classification method is applied data having 16 features.

According to number of neighbors, obtained result is given below in Table 5.1. It shows when the number of neighbor’s changed, what performance has been done. Before ‘k’ changes, Euclidean method is set for calculating distance.

Table 5.1 According to number of neighbors, changing performance with Euclidean distance method

'k' number of neighbors	Accuracy	Error Rate	Distance
1	0.97	0.03	Euclidean
3	0.9533	0.05	Euclidean
5	0.96	0.04	Euclidean
7	0.9433	0.06	Euclidean
9	0.5867	0.41	Euclidean
11	0.44	0.56	Euclidean

According to table, the highest performance is 97.0% for k=1 and distance method is Euclidean.

The table 5.2 below illustrates the number of samples classified correctly from all classes having 5 samples. Euclidean is used as distance method and k=1 is set. The system has revealed 100% success for classes giving the result 5.

Table 5.2 Number of correct classification for each sample

Class Name	Number of Correct Classified Samples	Class Name	Number of Correct Classified Samples
1. Class	5	16. Class	5
2. Class	5	17. Class	5
3. Class	4	18. Class	5
4. Class	5	19. Class	5
5. Class	5	20. Class	5
6. Class	5	21. Class	0
7. Class	5	22. Class	5
8. Class	5	23. Class	5
9. Class	5	24. Class	5
10. Class	5	25. Class	5
11. Class	5	26. Class	5
12. Class	5	27. Class	5
13. Class	5	28. Class	5
14. Class	5	29. Class	5
15. Class	5	30. Class	5
Class Name	Number of Correct Classified Samples	Class Name	Number of Correct Classified Samples
31. Class	5	46. Class	5
32. Class	5	47. Class	5
33. Class	5	48. Class	5
34. Class	5	49. Class	5
35. Class	5	50. Class	5
36. Class	5	51. Class	5
37. Class	5	52. Class	5
38. Class	5	53. Class	5
39. Class	5	54. Class	5
40. Class	5	55. Class	4
41. Class	5	56. Class	5
42. Class	5	57. Class	5
43. Class	5	58. Class	5
44. Class	5	59. Class	5
45. Class	5	60. Class	3

The table 5.3 is given when City Block method is set for calculating distance of the performance.

Table 5.3 According to number of neighbors, performance changing with City Block distance method

'k' number of neighbors	Accuracy	Error Rate	Distance
1	0.97	0.03	City Block
3	0.97	0.03	City Block
5	0.9667	0.04	City Block
7	0.9633	0.04	City Block
9	0.70	0.3	City Block
11	0.5333	0.47	City Block

According to the table, the highest performance is %97.0 for k=1 and k=3, when distance method is City Block.

The table 5.4 below illustrates the number of samples estimated correctly from all classes having 5 samples. City Block is used as distance method and k=3 is set.

Table 5.4 Number of correct classification for each samples

Class Name	Number of Correct Classified Samples	Class Name	Number of Correct Classified Samples
1. Class	4	16. Class	5
2. Class	5	17. Class	5
3. Class	0	18. Class	5
4. Class	5	19. Class	5
5. Class	5	20. Class	5
6. Class	5	21. Class	4
7. Class	5	22. Class	5
8. Class	5	23. Class	5
9. Class	5	24. Class	5
10. Class	5	25. Class	5
11. Class	5	26. Class	5
12. Class	5	27. Class	5
13. Class	5	28. Class	5
14. Class	5	29. Class	5
15. Class	5	30. Class	5

Table 5.4 Continue

Class Name	Number of Correct Classified Samples	Class Name	Number of Correct Classified Samples
31. Class	5	46. Class	5
32. Class	5	47. Class	5
33. Class	5	48. Class	5
34. Class	5	49. Class	5
35. Class	5	50. Class	5
36. Class	5	51. Class	5
37. Class	5	52. Class	5
38. Class	5	53. Class	5
39. Class	5	54. Class	5
40. Class	5	55. Class	4
41. Class	5	56. Class	5
42. Class	5	57. Class	5
43. Class	5	58. Class	5
44. Class	5	59. Class	5
45. Class	5	60. Class	4

According to the works, the highest performance is %97.0 for 16 features and classification method k-NN.

In case the data, on which feature analysis has been made, are decreased after these studies according to the values obtained, studies on data constitute of 14 features are examined. The purpose is maximum success rate.

When the k value is determined as 3, and the distance method as City Block, the highest success rate achieved is 96.67%. When there is a change in the 'k' value and distance method, the success rate achieved is lower than 97.0%.

### ***5.1.2 Linear Discriminant Analysis***

Linear Discriminant Analysis (LDA) is another known algorithm for classification problems. It works by guaranteeing maximum ratio of between-class variance and within-class variance in a data set.

The main idea of the LDA is finding linear transformation of sets by using the most distinguishable feature sets after transformation.

### 5.1.2.1 Algorithm

In the case where there are more than two classes, the analysis used in the derivation of the Fisher discriminant can be extended to find a subspace which appears to contain all of the class variability. Suppose that each of  $C$  classes has a mean  $\mu_i$  and the same covariance  $\Sigma$ . Then the between class variability may be defined by the sample covariance of the class means (Rao, R. C., 1948)

$$\Sigma_b = \frac{1}{C} \sum_{i=1}^C (\mu_i - \mu)(\mu_i - \mu)^T$$

where  $\mu$  is the mean of the class means. The class separation in a direction  $\vec{w}$  in this case is given by

$$S = \frac{\vec{w}^T \Sigma_b \vec{w}}{\vec{w}^T \Sigma \vec{w}}$$

“This means that when  $\vec{w}$  is an eigenvector of  $\Sigma^{-1} \Sigma_b$  the separation will be equal to the corresponding eigenvalue. Since  $\Sigma_b$  is of most rank  $C - 1$ , then these non-zero eigenvectors identify a vector subspace containing the variability between features”. (Rao, R. C., 1948)

### 5.1.2.2 Linear Discriminant Analysis Tests

After the theoretical explanations about the Linear Discriminant Algorithm, this algorithm was used in our dataset as follows.

Firstly, Leave One Out-Cross Validation Method is used for testing and training data can be selected from our database. 299 pieces sample are used for training and 1 pieces sample is used for testing. This event is repeated 300 times. All test results are saved as variable. Original classes of test samples and classification results are compared. All tables are shown respectively.

Then, Linear Discriminant Analysis is implemented with a matrix having 16 features. Maximum result is strived to be achieved by using different variants. Then a classification is made with features found as a result of the analysis.

Table 5.7 Eigen Values

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	184,660 <sup>a</sup>	30,8	30,8	,997
2	129,769 <sup>a</sup>	21,7	52,5	,996
3	79,443 <sup>a</sup>	13,3	65,8	,994
4	51,535 <sup>a</sup>	8,6	74,4	,990
5	43,098 <sup>a</sup>	7,2	81,6	,989
6	30,069 <sup>a</sup>	5,0	86,6	,984
7	21,220 <sup>a</sup>	3,5	90,1	,977
8	18,660 <sup>a</sup>	3,1	93,2	,974
9	12,230 <sup>a</sup>	2,0	95,3	,961
10	10,488 <sup>a</sup>	1,8	97,0	,955
11	5,541 <sup>a</sup>	,9	98,0	,920
12	5,154 <sup>a</sup>	,9	98,8	,915
13	2,924 <sup>a</sup>	,5	99,3	,863
14	2,046 <sup>a</sup>	,3	99,7	,820
15	1,335 <sup>a</sup>	,2	99,9	,756
16	,759 <sup>a</sup>	,1	100,0	,657

Eigenvalue refers to the correlation between variables. The Eigen values are shown in Table 5.7.

To find a variable describes how much of the variance in one factor is the square of the factor loading. The Table 5.8 in below shows these results. Wilk's Lambda tests the significance of eigenvalue statistic.

Table 5.8 Wilks' Lambda

Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 16	,000	11578,291	944	,000
2 through 16	,000	10214,848	870	,000
3 through 16	,000	8942,883	798	,000
4 through 16	,000	7797,733	728	,000
5 through 16	,000	6763,786	660	,000
6 through 16	,000	5775,535	594	,000
7 through 16	,000	4878,683	530	,000
8 through 16	,000	4069,327	468	,000
9 through 16	,000	3291,917	408	,000
10 through 16	,000	2617,881	350	,000
11 through 16	,001	1980,693	294	,000
12 through 16	,003	1490,512	240	,000
13 through 16	,020	1016,239	188	,000
14 through 16	,080	659,404	138	,000
15 through 16	,243	368,729	90	,000
16	,568	147,406	44	,000

After these parameters are shown, obtained accuracy rate by LDA is 97.7%.

The Table 5.9 below illustrates the number of samples estimated correctly from all classes having 5 samples. According to this table, 3., 21., 38. and 60. classes are distinguished less than other classes.

Table 5.9 Number of correct classification for each sample

Class Name	Number of Correct Classified Samples	Class Name	Number of Correct Classified Samples
1. Class	5	16. Class	5
2. Class	5	17. Class	5
3. Class	1	18. Class	5
4. Class	5	19. Class	5
5. Class	5	20. Class	5
6. Class	5	21. Class	4
7. Class	5	22. Class	5
8. Class	5	23. Class	5
9. Class	5	24. Class	5
10. Class	5	25. Class	5
11. Class	5	26. Class	5
12. Class	5	27. Class	5
13. Class	5	28. Class	5
14. Class	5	29. Class	5
15. Class	5	30. Class	5
Class Name	Number of Correct Classified Samples	Class Name	Number of Correct Classified Samples
31. Class	5	46. Class	5
32. Class	5	47. Class	5
33. Class	5	48. Class	5
34. Class	5	49. Class	5
35. Class	5	50. Class	5
36. Class	5	51. Class	5
37. Class	5	52. Class	5
38. Class	4	53. Class	5
39. Class	5	54. Class	5
40. Class	5	55. Class	5
41. Class	5	56. Class	5
42. Class	5	57. Class	5
43. Class	5	58. Class	5
44. Class	5	59. Class	5
45. Class	5	60. Class	4

In section 4.5, feature analysis has been made, after these studies according to the values obtained, Linear Discriminant Analysis method has been implemented with 14 features.

When 14 features are used for classification, obtained accuracy rate is 97.0%. This value is lower than the accuracy rate which is obtained by using 16 features.

## **5.2 Comparing Results**

After two classification methods are applied and the results are obtained, all results can be compared. The result obtained with k-NN method is %97.0 but it is %97.7 with Linear Discriminant Analysis which gives us the best results. According to obtained classification results, geometric features and used Linear Discriminant Analysis classifier are good choices for hand recognition systems.

## **CHAPTER SIX**

### **CONCLUSIONS**

#### **6.1 Overview of the Project**

This project basically aims to recognize people, based on biometric parameters of the hand. The process in hand recognition system is to create a database which allows hand image samples of some subjects to be recognized. These hand images are created by CCD camera. They are resized in MATLAB. The database of hand images are prepared to be processed in MATLAB. And then created database is turned into a matrix which includes numerical data such as features of images. The resulting data is saved to memory of MATLAB.

Test and training data are prepared in MATLAB for using in the k-NN Method. But for using the other classification method which is Linear Discriminant Analysis, test and training data are prepared in SPSS.

#### **6.2 Advantages and Disadvantages of the System**

The purpose of this system is recognition. Some controls are usually needed to be made by other people, but this problem is solved by hand recognition system. The people have different properties on their hands. Therefore, it is easy to distinguish people from each other by their hands.

For example, in large factory, enter/exit controls don't have to be made by a person. This is a difficult and a time consuming task to follow. By the aid of this hand recognition system, controls are easier.

Some differences are found in this study as distinctly from other recognition systems. For example, since a good image processing has been made, it has been possible to make feature calculation even in pictures with pixel loss. Images of hands bearing accessories are available. The success rate is very high.

This system cannot separate a fake image from real hand images. It may be seen as the biggest problem of the developed hand recognition system. But this problem can be solved by adding some sensors to the system. For example, nowadays infrared cameras are used. Therefore real hand image is separated from a fake image easily and additional features are obtained from infrared images.

### **6.3 Software Tools and Equipment Specifications**

MATLAB and IBM SPSS have been used during the development of the project. System development required MATLAB environment which has been already installed in the computers. The MATLAB information is given below.

-Version 7.12.0.635(R2011a)

-32 bit (win32)

The IBM SPSS information is given below.

-Version 20

-32 bit

A wood board has been used to take a hand images in a illumination controlled environment. Background of the box is covered with matte black cloth and side of the box is covered with matte black material.

### **6.4 Comparison with Other Projects**

There are a lot of people who study hand recognition systems. These people obtained success rates by using some classification methods and using features, which are shown in Table 6.1 and 6.2.

The studies conducted are about hand recognition systems, and they have many differences. Some researchers have made changes in features as distinct from this study, and some researchers have made changes in the classification method. A comparison is made for both cases and are summarized in tables.

First of all, in a comparison made with studies using geometric features, Table 6.1 below is given. Here what defined as ‘Success’ is the accuracy value of the system.

Table 6.1 Results of the other projects

<i>Author</i>	<i>Database</i>	<i>Name of Study</i>	<i>Classification Method</i>	<i>Success</i>
Alexandra L.N. Wong Pengcheng Shi Department of Electronic and Electrical Engineering Hong Kong University of Science and Technology	323 right- hand images	Peg-Free Hand Geometry Recognition	Gaussian Mixture Model	88.89% (True Accept Rate)
Yaroslav Bulatov Sachin Jambawalikar Piyush Kumar Saurabh Sethia	714 hand images from 70 people.	Hand Recognition Using Geometric Classifiers	Minimum Enclosing Ball Classifier	Above 99% (True Accept Rate)
Vandana Roy and C. V. Jawahar Centre for Visual Information Technology, International Institute of Information Technology, Gachibowli, Hyderabad, India	40 users with 10 samples from each user	Feature Selection for Hand- Geometry Based Person Authentication	Fisher Discriminant Analysis	91.67% (Accuracy)

According to the table, the success achieved in the study using geometric features, is lower than the success achieved in this study.

The studies of researchers using the methods in this study as classification method are illustrated in the Table 6.2. The studies include classification using serious features. Here what defined as success is the accuracy value of the system.

Table 6.2 Comparing the other results

<i>Author</i>	<i>Database</i>	<i>Name of Study</i>	<i>Used Features</i>	<i>Classification Method</i>	<i>Success</i>
Gholamreza Amayeh	101 subjects with 10 images	A Component-Based Approach to Hand Based Verification and Identification System	High-Order Zernike Moments	Linear Discriminant Analysis	98% Score-Level Fusion
Vit Niennattrakul Dachawut Wanichsan and Chotirat Ann Ratanamahatana Department of Computer Engineering, Chulalongkorn University	From 22 people with 6 to 7 images for each person	Hand Geometry Verification Using Time Series Representation	Time Series	Centroid-Based Technique	83.50% (True Accept Rate)
Juan Manuel Ramirez-Cortes Pilar Gomez-Gil Gabriel Sanchez-Perez David Baez-Lopez	10 samples from each subject, for 20 subjects	A Feature Extraction Method Based on the Pattern Spectrum for Hand Shape Biometry	Morphological Pattern Spectrum	Minimum Euclidean distance classifier	%97.2 (Accuracy Rate)
				k-nearest neighbor (k=3)	%98.0 (Accuracy Rate)
				Neural network	%98.5 (Accuracy Rate)

According to the table while success rates achieved are close to each other, maximum success with 98.5% has been achieved with Neural Network method. This study was conducted by Juan Manuel Ramirez-Cortes, Pilar Gomez-Gil, Gabriel Sanchez-Perez, and David Baez-Lopez.

In the other projects, obtained results are good. According to these results, hands can be used for recognition systems because the purpose of recognition system is maximum success. %97-%99 successes can be considered maximum success.

## **CHAPTER SEVEN**

### **FUTURE WORK**

Sixteen geometric features and three classification methods are used in this study. Beside the success rate achieved indicates that a good classification has been made, as it bears an error rate, different methods should be tried for better results.

Due to some problems depending on geometric features, such as using printed images instead of real hands, there are some considerations for future works. Using infrared camera is planned for acquiring hand images. Therefore, showing capillaries by infrared CCD eliminate the risk of fake images, as people have different vascular shapes. Recently, some banks use this system with infrared camera for identification.

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## **APPENDIX**

An “Appendix CD” is prepared which contains all MATLAB files and SPSS files, hand images of people that are used in this thesis.

There are sub-program, main program and database that include hand feature values in CD. Main programs consist of four parts.

First main program’s name is ‘Features’ which includes image processing and feature extraction works.

‘Classification\_KNN\_Method\_16Features’ which includes using k-NN method works with 16 features.

‘Classification\_LDA\_Method\_16Features’ which includes Linear Discriminant Analysis works with 16 features.

Database’s name is ‘handdata\_16Features.mat’ that have 16 features.

Hand images are numbered from 1 to 300 to make using the software easier.