Farsi Handwritten Databases and Offline Handwritten Isolated Digits Recognition

Farshid Solimanpour

A Thesis
in
the Department
of
Computer Science and Software Engineering

Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Computer Science at
Concordia University
Montreal, Quebec, Canada

January 2007

Your file Votre référence
ISBN: 978-0-494-28955-6
Our file Notre référence
ISBN: 978-0-494-28955-6

ABSTRACT

Farsi Handwritten Databases and Offline Handwritten Isolated Digits Recognition

Farshid Solimanpour

This thesis describes an important step towards the standardization of the research on Optical Character Recognition (OCR) in Farsi language. It includes the development of several novel and standard Farsi handwritten databases, consisting of Farsi isolated digits, isolated letters, numerical strings, legal amounts on cheques, dates, and English isolated digits. Despite conventional research and an Internet search, to the best of our knowledge, no publicly accessible handwritten Farsi database exists that is available to researchers. In a character recognition system, three data sets are usually required:

1. Training set for training the classifier using designed features,
2. Verifying set for checking and adjusting the designed system,
3. Testing set to finally measure the performance of the system.

To cover all the specified requirements, all our databases contain complete sets of training, testing, and verifying samples.

Data entry forms were used for collecting handwritings. To process those forms, some form processing techniques were used to automate the process of extracting images of different fields in the forms, and to segment the numerical strings into isolated digits.

Included in this thesis, is the implementation of a recognition system for recognizing our handwritten Farsi isolated digits database which may be used for comparison with the results of future research. For this recognition system, we used three feature sets including outer profiles, crossing counts and projection histograms; and for classification we used Support Vector Machines with an RBF kernel which gave us a recognition rate of 97.46% on our Testing Set. We also applied a rejection method to our system, which could improve the error rate by 1.18% by a rejection rate of 2.94%.

Acknowledgements

I would like to express my sincere gratitude to my supervisor, Professor Ching Y. Suen, for all his support and informative feedback.

I am also grateful to my dear colleague, Mr. Javad Sadri for all his help and support, to Ms. Shira Katz for editing this thesis, and all the writers who filled out my handwritten sample collection forms.

Last but not least, my greatest thanks and appreciation are reserved for my beloved wife, Khatereh, who supported me at all times, and without her help, encouragement, patience, sacrifice, and love I could not have possibly finished this work.

To Khatereh

Table of Contents

List of Figures

List of Tables

CHAPTER 1

Introduction

Character Recognition by computers is one of the most challenging areas in pattern recognition. It has been decomposed into smaller sub-areas by researchers seeking a human-equivalent performance. It involves on-line character recognition, where the user needs to use an electronic pen to write on a paper-like electronic plate; and it involves off-line character recognition where the user has more freedom in selecting the writing material. In the real world, people have to fill out all sorts of forms all the time, and perhaps off-line recognition has more practical applications. Although there have been revolutionary changes in both software and hardware during the past 20 years, there are still many technical issues to overcome in order to make handwriting practical for the human interface with computers [1 ,2].

In an off-line handwritten recognition system, utilization of a database of handwritten characters, numbers and other symbols is essential, in order to evaluate the effectiveness of a developed method, technique or software. Also, an important part of the development and evaluation of such system is the comparison with the results of other researchers in the same standard database [3]. A lot of previously developed databases exist for different languages, but to the author's best of knowledge no publicly available (freely or commercially) handwritten database exists for the Farsi language. This matter plus all other reasons previously mentioned were the motivation of this work.

In this report we will first describe the construction of six Farsi handwritten databases; handwritten numerical strings, isolated digits, isolated letters, legal amounts, Farsi dates (called Hijri Shamsi*), and English digits. Next we present a recognition system that we created for our isolated digits database. The uniqueness of this experiment, in addition to its high recognition rate relies on the fact that it will serve as a basis for comparison of the methods and results to be reported by other researchers.

Furthermore, a major advantage of this study is that it can be adjusted easily to serve more than 30 different countries which use languages with similar alphabet and sets of numerals as Farsi (e.g. Arabic, Urdu, Pashto, etc.) written by a combined population of more than 300 million.

1.1 Farsi and Related Languages

Farsi consists of 32 letters and 10 digits. Unlike the Latin-based languages such as English, which are written from left to right, it is written from right to left. Farsi is a cursive language, which means that within one word, letters can be

---

* The word by word translation of "Hijri Shamsi" is "Emigrational Solar" which refers to the type of date that is calculated based on the amount of time the Earth takes to orbit around the Sun.

connected. In Figure 1 the word "Farsi" in the Farsi language is presented. In this figure, to understand the nature of the right to left order of the letters, the first letter representing "F" in the word "Farsi" is denoted by 1, the second letter by 2, and so on. Also, this word consists of 5 letters and out of those 5 letters; letters 1 and 2; and, 4 and 5 are connected to each other.

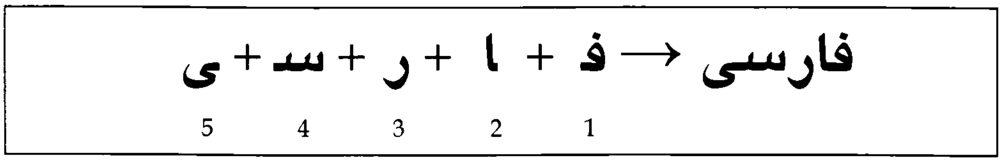


Figure 1 The word "Farsi" in the Farsi language consists of 5 letters.

Due to connectivity, the shape of a Farsi letter may change significantly depending on: its position in a word, the identity of neighboring letters, the writing font, and the way a writer connects successive letters. Due to these difficulties, when filling out forms, it is preferable to acquire the user's input by isolated letters; and this was our motive to create the isolated letters database. Figure 2 shows how the word "Kabaab" in the Farsi language is written when it is decomposed into isolated letters.

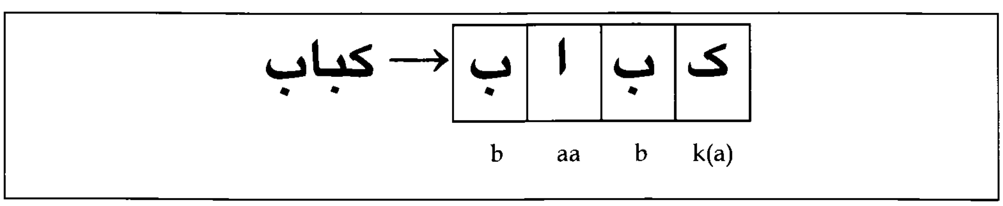


Figure 2 The word "Kabaab" in the Farsi language decomposed into <u>isolated letters</u>.

In Farsi, numbers are written from left to right exactly as they are written in other languages, including English. This makes it particularly difficult for researchers working on Farsi texts mixed with numbers or English words. Figure 3 shows digits used in Farsi, and their English equivalents. Figure 4 also shows how a mixed Farsi text should be interpreted regarding being right-to-left or left-to-right.

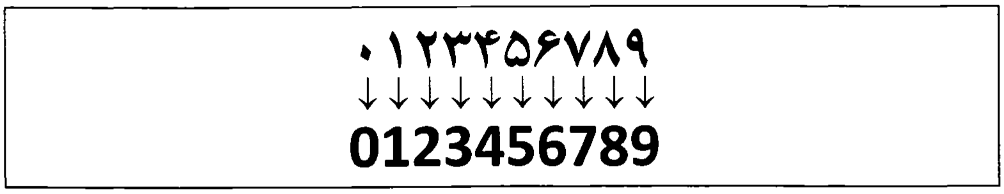


Figure 3 Farsi digits and their equivalent forms in English

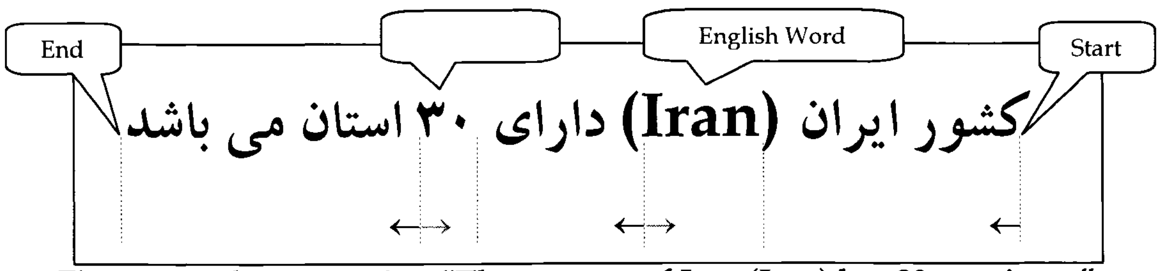


Figure 4 The expression "The country of Iran (Iran) has 30 provinces" shows how right to left Farsi text is mixed with left to right numbers or English words

As stated before, languages including Arabic, Urdu, Pashto, and a few more, use the same alphabets and digits as Farsi and researchers who work on those languages can benefit from different subsets of our databases. For example, the Arabic alphabet has 28 letters, which is exactly the same as the Farsi alphabet, except that it is lacking 4 letters shown in Figure 5. A complete list of letters and numbers used in the Farsi alphabet can be found in Appendix B.

پ ژ گ چ

Figure 5 The four letters of the Farsi language which are not included in the Arabic language alphabet.

There are also some differences between Arabic and Farsi in the style of writing digits that most people usually follow. Therefore, people used different styles when filling out our data entry forms. Table 1 shows differences in printed numbers (digits 4, 5 and 6 have different styles) and 0Table 2 shows differences in handwritten numbers (digits 2, 3, 4, 5, and 6 have different styles). Both Farsi speaking and Arabic speaking people use all the shown styles which are covered in our isolated digits database. The complete list of digits including their pronunciations is presented in Section B.2.

Table 1 Differences of printed numbers in Farsi and Arabic

	0	1	2	3	4	5	6	7	8	9
Farsi	۰	۱	۲	۳	۴	۵	۶	۷	۸	۹
Arabic	٠	١	٢	٣	٤	٥	٦	٧	٨	٩

Table 2 Differences of handwritten numbers in Farsi and Arabic

	0	1	2	3	4	5	6	7	8	9
Farsi	۰	۱	۲	۳	۴	۵	۶	۷	۸	۹
Arabic	٠	١	٢	٣	٤	٥	٦	٧	٨	٩
				۲						
				۳						

1.2 Previous Work

There are many examples of well-known databases in the field of handwriting recognition such as: NIST English isolated digits [4], CEDAR words [5], CENPARMI isolated English digits [6], UNIPEN isolated English digits [7], CENPARMI Arabic cheques [8], IFN/ENIT Arabic Words [9], ETL9 Japanese characters [10], and PE92 Korean characters [11]. However, there has been no Farsi database available to researchers despite the search that we did on the Internet and on research materials that have been available to us.

All the research on Farsi handwritten recognition has relied on privately collected and kept databases. For example [13] gathered 9000 samples from 90 persons and assigned 50 of them to the training set, and 40 to the testing set, and then removed bad samples. In [12] 2600 samples were collected from 200 people, and 13 classes were used (two styles were used for digits 0, 4, and 6). In [14], 200 writers contributed to creating the database of handwritten samples and it created afterwards an isolated digits database of 480 samples for 8 digit, and 100 samples for 32 letters; the digits 0 and 3 were not included in the database because they were not used in the postal system of Iran; also the letter forms "ـه" and "آ" (alternate styles of the letters "Heh" and "Alef") which are used in the forms were not covered. All other works except [17] which used the isolated Indian digits of CENPARMI's Arabic Cheques database, collected their own samples to be used in their research.

It is noticeable that each research group in the field of handwritten Farsi databases used a completely different set of handwritten samples collected for their specific research and this even applies to the works that have been done in the same lab (e.g. [12] and [14]). This makes it hard and sometimes almost impossible to compare different methods and works. Accordingly it would be difficult to improve the developed methods. This shows that how important availability of a Farsi handwritten database is. This has been our main motivation to start developing a set of handwritten Farsi databases that can be used in different fields of handwritten recognition research. Therefore, we decided to cover letters, numbers, dates, and legal amounts.

As partly presented, all the previous research was done using two datasets: Training Set, and Testing Set; however, having an extra set seemed necessary as a recognition system always needs to be adjusted, and using Training Set for this step could result in memorizing the samples (instead of learning them). Hence, it would be better and closer to the real situation that this step would be done using a set of samples different from the Training Set. Obviously this set of samples should not be the same as the testing set. Hence, we planned for a separate set of samples named Verifying Set.

The main contribution of this work has been in the area of creating the handwritten databases; however, to show the use of the databases, we also conducted a recognition experiment on the isolated digits database that we created. Unfortunately very few works have been reported in the field of Farsi handwritten recognition and not all the results are satisfactory.

For example in [12] (1995), M. H. S. Shahreza et al. could reach a recognition rate of 97.8% on isolated digits using shadow coding. For doing this, a 32-segment mask is overlaid over the sample image and then features are calculated by projecting the image pixels into these segments. A similar method was used by A. Harifi et al. in [15] (2004) using a 12 segment mask designed for Farsi digits based on the idea of a 7-segment display for English digits. In [16] (1999) by F. N. Said et al. (1999), reported a recognition rate of 94% by first resizing the sample image to an image of size 16 x 20, and then feeding the pixel values of the normalized image as a feature vector into a neural network, where the number of the hidden units for the neural network classifier, is determined dynamically.

J. Sadri et al. in [17] (2003), used outer profiles of sample images from 4 main directions as the feature vector. Then each of these profiles is represented as a one-dimensional signal. The derivative of each of these signals is represented by a vector of size 16, where these vectors constitute the feature vector. They reported a result of 94%.

H. Soltanzadeh et al. in [13] improved the method presented in [17] by using outer profiles from 8 directions, and adding more features like crossing counts and projection histograms and size. They did a comprehensive test using the SVM classifier with RBF and Polynomial kernels and different types of feature vectors, and managed to get a recognition rate of 99.57% which is the best result reported so far. Although comparing these works is hard since each individual work used a different database, the high recognition rate achieved by this work motivated us to implement a similar recognition system, and test it on our database. Our recognition system will be described in Chapter 4.

Reference [13] used 4 sets of features including outer profiles, crossing counts from 2 directions, projection histograms, and one size feature. These features were extracted from different directions, and were tested separately using 2, 4, and 8 directions. Figure 6 (copied from their paper) shows the projection histogram of one digit from 8 directions. The size feature was a simple Boolean feature added as a discriminator for zero. The characteristics of zero which calls for this special care are discussed in Section 2.4. Each feature was resampled to an array of size eight and then smoothened using a low pass filter. The size of the final feature vector was $32n+1$ where n is the number of directions.

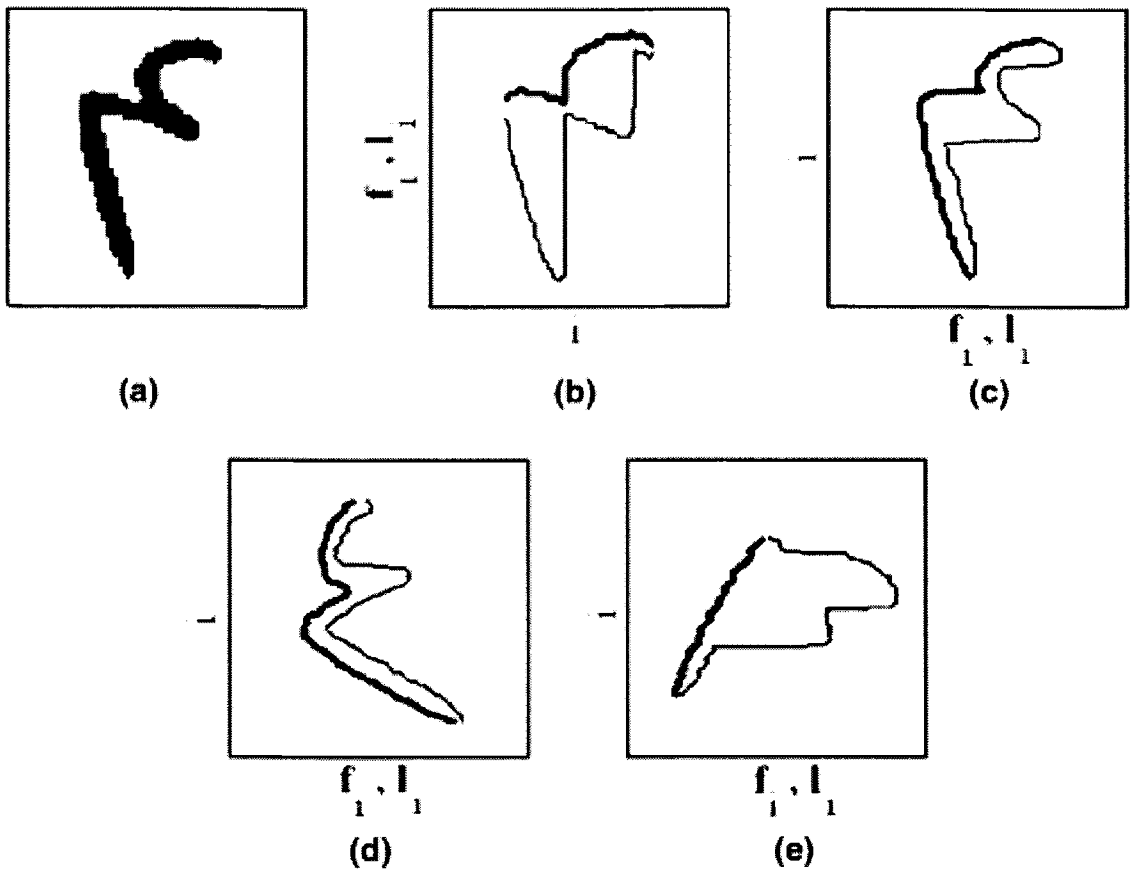


Figure 6 Outer profiles of a digit image. a) Original image, b–e) the image profile at horizontal, vertical, diagonal (45°) and off-diagonal (135°) orientations, respectively. In each image, the first and last profile diagrams are depicted with thick and thin lines, respectively.

1.3 Conference Presentation

This report, in the form of a brief paper, has been accepted and presented at the 10th International Workshop on Frontiers in Handwriting Recognition (IWFHR, 2006) which was held in La Baule, France, on October 23-26, 2006.

1.4 Outline of Forthcoming Chapters

Chapter 2 describes the data collection, including the steps in designing the data entry forms. In Chapter 3, data preparation and extraction from the filled forms are covered. Chapter 4 presents details of the created databases including the content and statistics. Chapter 5 introduces our recognition system for recognition of offline isolated Farsi digits and describes the features used. Chapter 6 gives an introduction to the Support Vector Machines which will be used in the classifier part of our recognition system. Chapter 7 includes details of our recognition experiments and the results. Finally, in Chapter 8, some concluding remarks and suggestions for future research are presented.

CHAPTER 2

Data Collection

2.1 Background

Data entry forms were used for collecting handwriting samples for our databases. Because data collection was a time-consuming part of the work and needed interactions with people; therefore, a decision was made to collect as many data types as possible in one run. These databases were targeted:

- Farsi Numerical Strings
- Farsi Isolated Letters
- Farsi Dates
- Farsi Isolated Digits
- Legal Amounts
- English Isolated Digits

From different ages, job categories, and genders, 175 writers were selected to fill out our two data-entry forms.

In the following sections we will first cover the general design of the data entry forms and then discuss the details of the design of each of these databases.

2.2 Data Entry Forms

Two data entry forms were designed for collecting handwritten samples. The data types in each form are described below and the complete list of individual fields in data entry forms is included in Appendix A. Throughout the forms we use fields for each number, word or expression. Each field is a box with a red border. On top of each box, what should be written in the box is printed. Figure 7 shows a sample of a field.

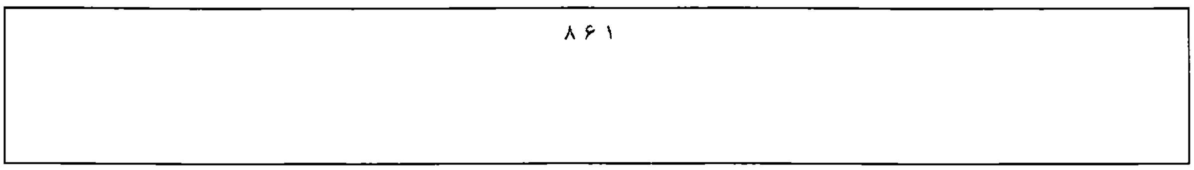


Figure 7 Sample of a data entry field for the number "861"

Two free fields are put in the data entry forms. One is the date field in Form 1, and the second is a legal amount in Form 2. In the date field, writers put their birth date, and in the free legal amount field, they can think of a legal amount, and write. This of course does not represent all the real situations where legal amounts appear on cheques, but it can be a start for researchers in this field.

In Figure 8 and Figure 9, the designed data forms are shown and different parts of the forms are denoted by letters as follows:

a) English isolated digits.

b) One free Farsi date.

c) Farsi numbers.

d) Farsi isolated characters.

e) 41 basic Farsi words that build legal amounts.

f) Rial (Currency Unit).

g) Toumaan (Currency Unit).

h) Tamaam (Over).

i) Moaadel (Equal to).

j) Three cursive legal amounts which will serve as testing data.

k) One free legal amount.

l) Edge identifier marks. These marks consist of four black squares that are placed at the corners of each form and by detecting the location of these marks, the developed program would be able to correctly calculate coordinates of the form and also to correctly determine the location of each field based on a designed form template (which will be explained in the section 3.4) (rather than expecting every field to be in its correct position which means relying on each form to be properly positioned in the scanner).

m) Form identifier marks. These are a Group of 8 squares used for identifying the form itself. These squares are numbered from 1 to 8 from right to left. For Form 1, squares 1, 5, and 8 were blackened and for Form 2, the blackened squares were 2, 4, and 7. Detecting this identifier enabled the program to automatically use the correct form template for each scanned image, thereby decreasing the amount of manual work.

n) In the page header, we give instructions on how to fill out the forms in Farsi. The translation of the text reads as follows:

   "Many thanks for your cooperation. For filling out the form, please note: • Write the text above each box, inside the box carefully by using a black ballpoint pen, fountain pen, or thin marker and with your normal handwriting • **Please prevent crossing out words.** If you made a mistake anywhere in the form, use correction tape to whiten it (in a way that would cover the underneath text completely and would not get embossed) and then write the text again; or you can simply fill out a new form • Please send the filled out form to our postal address (mentioned above) or if you would like to send it electronically, first scan it with a resolution of 300dpi, and then save it as a TIF file. For sending the form electronically, use this URL: `http://Lotrasoft.com/research`. By filling out this form, you can win a nice gift. You can read the details on our website. Please write your email address here to enable us to contact you in case you win. With many thanks."

We also provided a website for uploading data entry forms; however, no form was sent electronically. Therefore, it is a fact that all the forms were scanned using the same scanner mentioned in section 3.1.

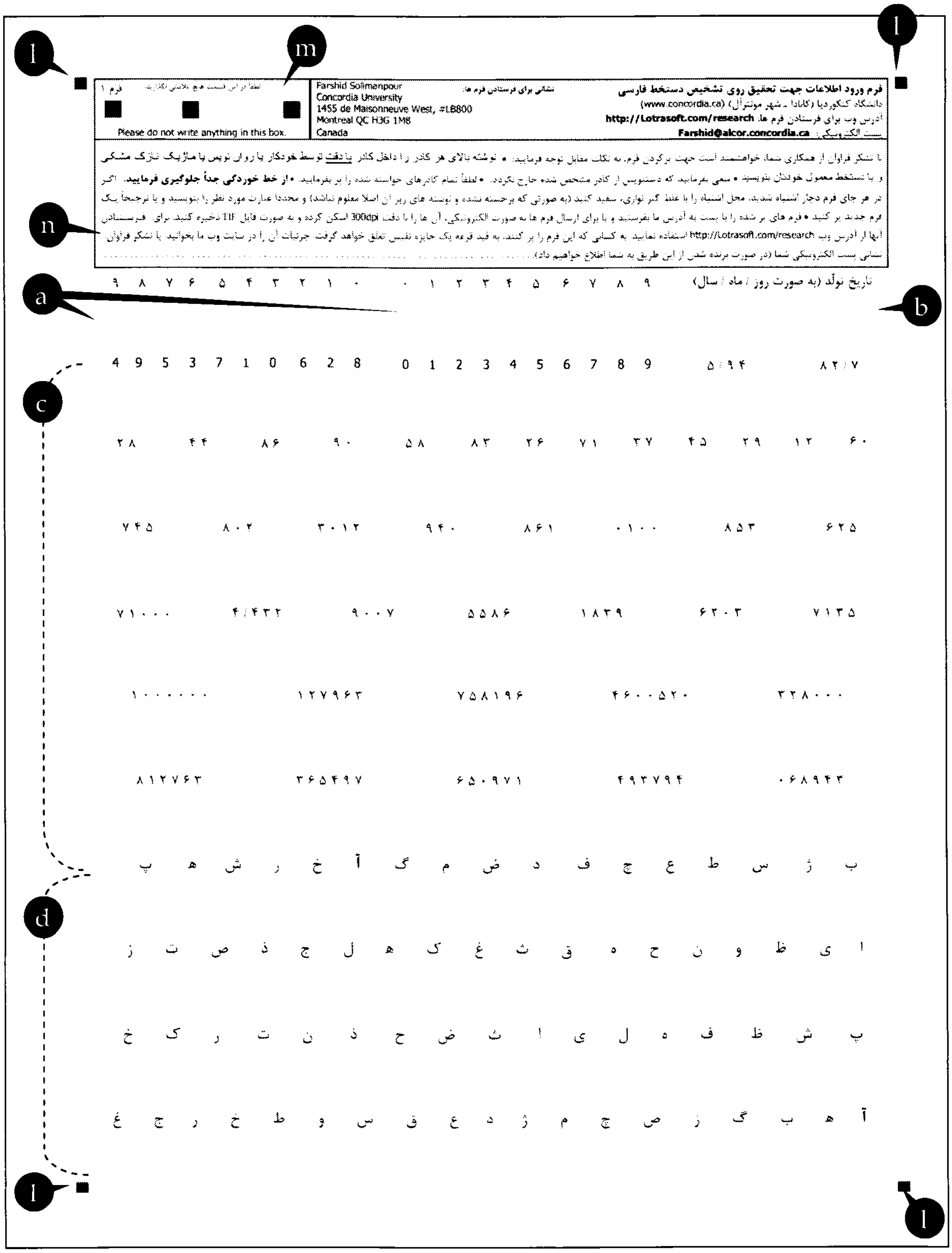


Figure 8 Data entry form 1.

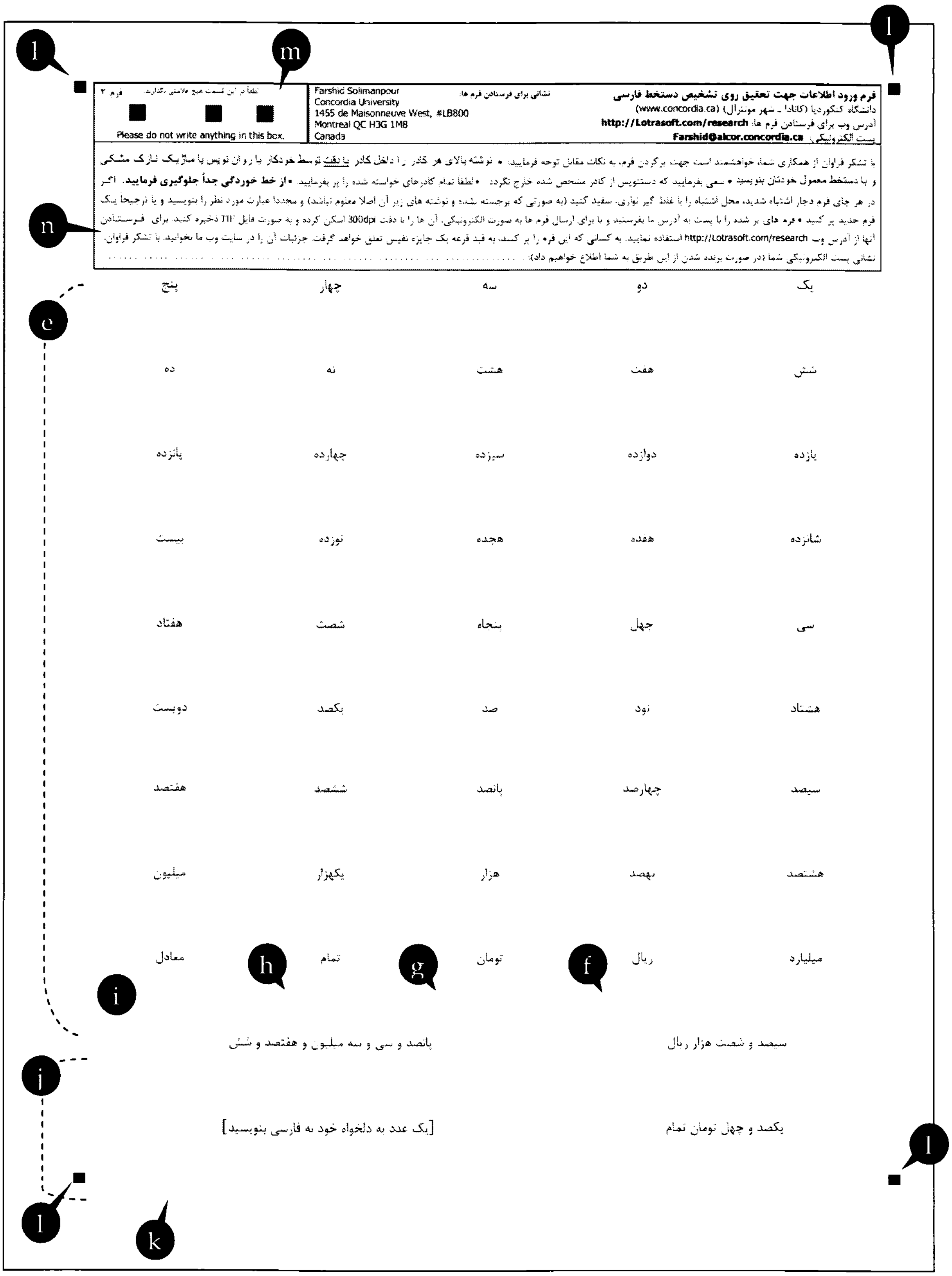


Figure 9 Data entry form 2

2.3 Farsi Numerical Strings and Isolated Digits

Forty-two numbers were chosen to form our database of Farsi numerical strings. Each number consisted of a different number of digits, and Table 3 shows the statistics of the numerical fields used in the data entry forms (grouped by the number of digits they had). A complete list of fields used in the data entry forms is included in Appendix A.

Table 3 Statistics of the numerical fields

Type of the Numerical String	Number of Fields
Two Digit	13
Three Digit	7
Three Digit Decimal	2
Four Digit	6
Four Digit Decimal	1
Five Digit	1
Six Digit	8
Seven Digit	2
Ten Digit (all 10 digits in order and reverse)	2
Total	**42**

We also decided to create an isolated digits database by segmenting the numerical strings; therefore, it was necessary to normalize the number of times that similar digits were repeated throughout them. Table 4 shows the number of repetitions for each digit and the decimal point used throughout the numerical strings. Figure 10 shows some samples of isolated Farsi digits.

Table 4 Statistics of the different field types used as numerical strings

Digit	0	1	2	3	4	5	6	7	8	9	Decimal Point
No. of repetitions	30	15	16	16	15	15	15	16	16	15	3

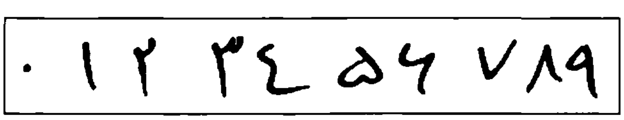


Figure 10 Samples of Farsi isolated digits

Because some digits were connected by the writers, separating all of the digits from the numerical strings was not possible. Therefore, for the final product, we decided to include only 1800 samples of each digit. For excluding digits from the sets we used a normalization algorithm which is described in Section 3.12.

2.4 Digit Zero

The digit "0" is a special case in Farsi. The normal height of the character "0" is approximately one fifth of the other characters and is written differently either because of its location in a numerical string or when it is repeated two or more times in a number. Because of its special characteristics, we repeated it 30 times throughout the numbers to cover all of the possibilities of its appearance in a numerical string. In Figure 11, two samples of the handwritten Farsi number "71000" can be viewed, which show two different styles of writing three zeros together ("000").

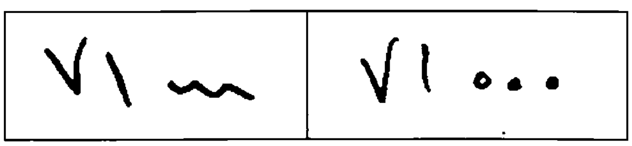


Figure 11 Samples of different styles of writing three zeros ("000") in the Farsi handwritten number "71000".

Throughout the numerical strings chosen for the data entry forms, these possibilities regarding the number of repetitions of the digit "0" in a number were covered:

- Repeated 1 time: 60, 90, 0100, 940, 3012, 802, 6203, 4600520, 068943, 650971
- Repeated 2 times: 0100, 9007, 4600520
- Repeated 3 times: 71000, 328000
- Repeated 6 times: 1000000

There could be more possibilities of repeating the digit zero, but usually people tend to write them as components of 1, 2 or 3 repeated zeros. For example the number: 10,000 is often written as two components: a "10" followed by "000" both of which are covered in our set of numbers. Offline recognition systems are based on segmentation rather than recognizing the whole expression; therefore, segmenting a number into separated components (connected sub-components) is the first step those recognition systems take for recognizing a number.

2.5 Farsi Decimal Point

The decimal point in Farsi looks exactly like the slash sign in English. Because the shape of the decimal point is a lot like the digit "1," special care should be applied when recognizing Farsi decimal numbers. Examples can be viewed in Figure 12, which shows a sample of the Farsi number "82.7" and Figure 13, which shows a sample of the number "71".

Figure 12 Sample of the Farsi number "82.7" (٨٢/٧)

Figure 13 Sample of the Farsi number "71" (٧١)

2.6 Farsi isolated letters database

As stated before, Farsi consists of 32 letters all of which are covered in our forms. In addition to those, we were aware that people usually use two different styles for the letter "ه" (pronounced: Heh) and "ا" (pronounced: Alef) when filling out forms. Therefore we included those styles in our set of Farsi letters in order to have a complete database. Samples of those styles are shown in Figures 14 and 15 respectively.

With those letters having two different styles, the number of isolated letters reached 34. We also repeated each letter twice. These 68 letters (34 x 2) were randomly put together in 4 data entry fields in Form 1. The program extracted these fields, then segmented them and saved each letter in a separate file in order to form the isolated letters database.

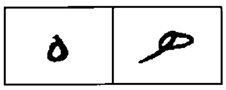


Figure 14 Two styles of writing the letter "ه" (Heh)

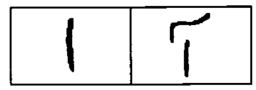


Figure 15 Two styles of writing the letter "ا" (Alef)

2.7 Farsi dates database

Most of the countries that have Farsi language speakers use a type of date called "Hijri Shamsi". The format of writing the date in Farsi is like this: **year/month/day**. A sample of a handwritten date is shown in Figure 16.

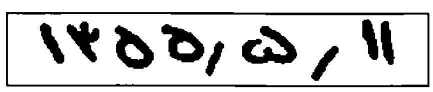


Figure 16 Sample of a handwritten Farsi date representing 1355/5/11

2.8 English digits

Collecting English digits has already been done by many researchers for different databases; however, a small set (2 fields) that in total had 2 of each digit, was included in Form 1. We hope that this database will enable future researchers to study the style of writing English digits by Iranians whose native language is not English.

2.9 Legal amounts

All techniques used for recognizing legal amounts on cheques require segmenting the amounts into words before recognizing them. There are 41 words that are used in different combinations to make legal amounts and we have covered all of them in our database. They include the numbers One to Twenty, Thirty to Ninety (multiples of 10), Hundred to Thousand (multiples of 100), Million, and Milliard. Added to those, are the words One-Hundred and One-Thousand, which in Farsi might be written differently than Hundred and Thousand. With those 41 words, legal amounts can be composed, up to 999,999,999. Cheques with the amount One Trillion (1,000,000,000) or more, in addition to being rare, are usually printed rather than handwritten.

It is important to note that in Farsi, the word "and" which is used in writing legal amounts, is written only by the letter "و" (pronounced: vāv, refer to Appendix B) and because samples of this Farsi letter were already collected in the isolated letters database, we did not include it in this database.

Currency units might also appear when writing legal amounts. For that reason, two official currency units used in Iran were also incorporated into this data set: the words "Rial", and "Toumaan".

There are two more words that might appear in legal amounts and are incorporated into our database: "تمام" (pronounced: tamām, meaning: over), and "معادل" (pronounced: moādel, meaning: equal to). These two words are just used to complement a legal amount, and they do not have an impact on the actual number itself. For example, an amount might be written as: "Two Thousand Rials Over" which is the same as "Two Thousand Rials". This is a security measure that individuals in Iran take to prevent others from adding words to a drawn cheque. A sample of Farsi handwritten legal amount can be seen in Figure 17.

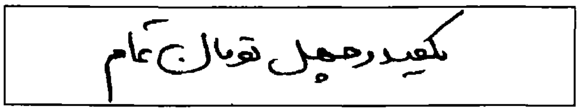


Figure 17 Sample of the Persian handwritten legal amount: "One Hundred and Forty Toumaans Over".

In order to have a better Testing Set, three predetermined fields and one free field (where writers were free to write a legal amount of their own) were added to Form 2. The free field was labeled manually after forming the database. The complete list of fields in data entry forms is included in Appendix A, and Samples of the data entry forms can be viewed in Section E.5.

CHAPTER 3

Data Extraction

In this chapter, we will describe the process of digitizing the data entry forms, and extracting images of the different fields by using a template to assemble the databases.

3.1 Scanning / Image Format

Each form was scanned using a Lexmark-P3180 scanner, whose resolution was set equal to 300 dpi at a grey level of 8 bits. The images were saved in PNG (Portable Network Graphics), indexed-color format files. PNG is an extensible file format for the lossless, portable, well-compressed storage of raster images. PNG provides a patent-free replacement for GIF and can also replace many common uses of TIFF and is widely recognized and used by researchers in both UNIX and Windows environments. Indexed-color, grayscale, and truecolor images are supported, plus an optional alpha channel for transparency. Sample depth can range from 1 to 16 bits per component (up to 48-bit images for RGB, or 64-bit for RGBA) **[12]** .

3.2 Color Coding

For all databases, grayscale images were first extracted, and then all of the images were converted to binary format, and saved in a separate folder keeping the original filename and the same folder structure as the grayscale folder. To convert each file to binary, the threshold of a grayscale image is calculated using Otsu's method [19], and then all of the pixels with a brightness less than that threshold value are set to black, and the rest to white. Both grayscale and binary versions of the images (which are located in separate folders with the same structure as stated before) are included in the final product.

3.3 Pre-Processing

The only pre-processing applied to the scanned forms was removing salt and pepper noise using the algorithm described in **[20]**. All other steps were left for future researchers who intend to use the database.

3.4 Designing data extraction template

A computer program was developed to automatically extract the images of the fields from the scanned forms. Using this program, we designed a template for our data entry forms and determined the boundaries for each field in the form, in addition to identifying the anchoring marks on each form. For each field in the template we also saved the database it belongs to and its label both of which were used in the extraction process to label the extracted image and to assign the image to the correct database. Figure 18 shows a screenshot of the program with the designed template and Figure 19 is a zoomed-in shot of the designed anchoring marks for Form 1 which shows the edge anchoring marks, and form identifiers.

The fields location in the template were saved as vector rather than pixels and due to this, our program was able to scale or rotate the template or do any other transformation necessary without losing precision.

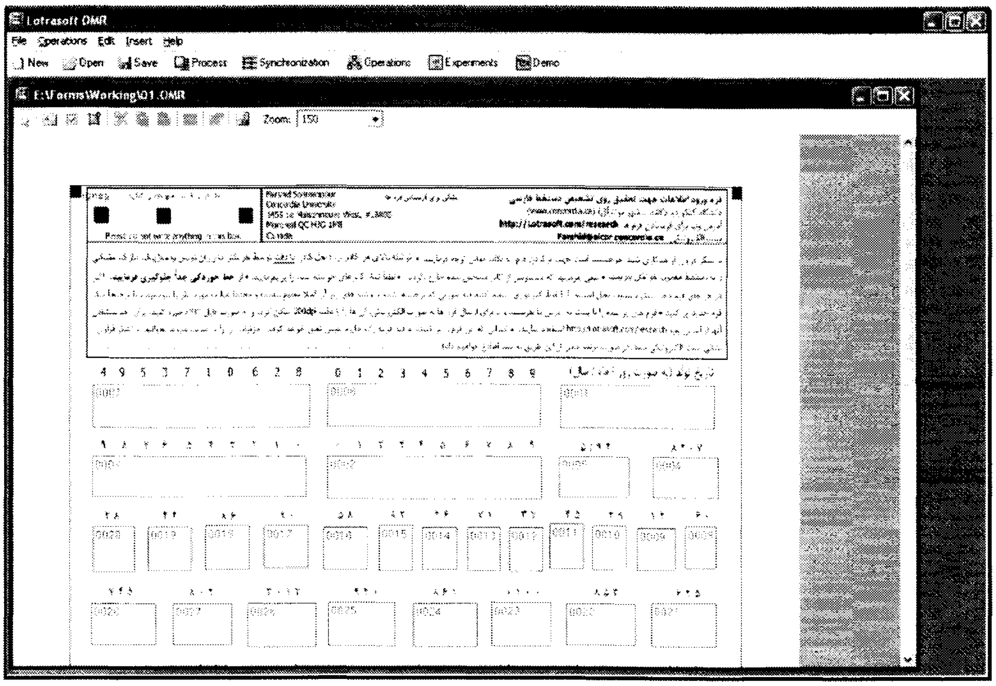


Figure 18 Design of the template of Form 1

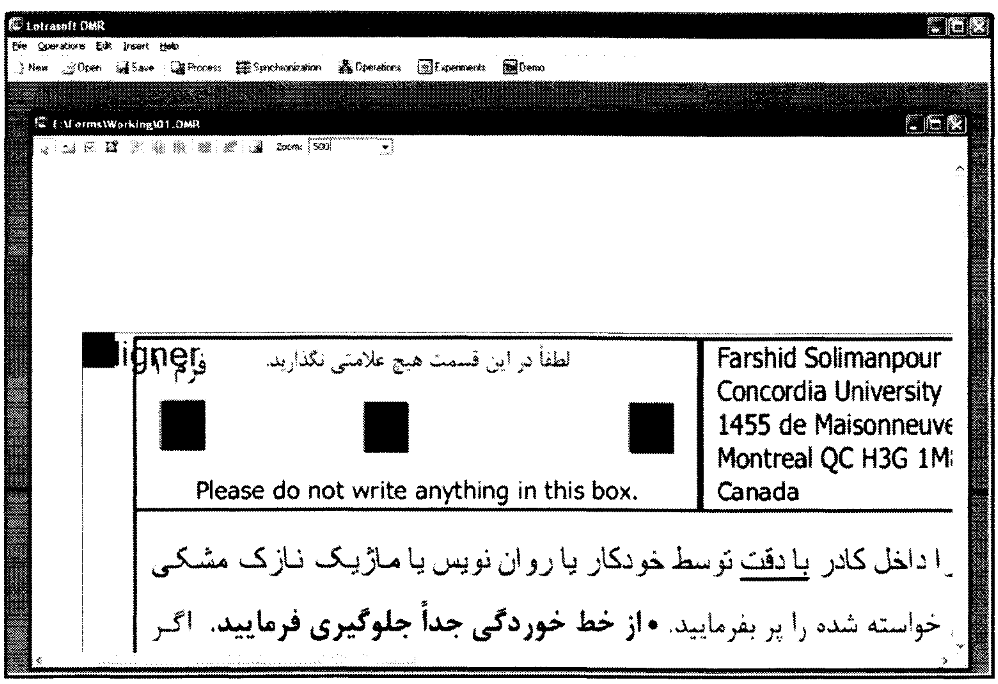


Figure 19 Design of corner anchoring marks and form indentifiers

3.5 Information Database (IDB)

Every image database has a way to store information about each image. Some use a text file which associates the filename to its label in each line of the text. Some use one text file for each image with the same filename, but a different extension, and some other methods. Usually these methods were used for portability of the database (being able to use it in different operating systems and applications), but we were looking for a method that gives us a better performance when searching, and also provides more information with less effort. This way, researchers could select the appropriate images for their work more easily, and get more useful information about them.

Microsoft® Access ™ format was selected to save information of the images. Although this software is proprietary; however, it is widely used in universities and gives searching capabilities that no other free software offers with that ease. Also if necessary, it can be converted easily to other formats supported by open source software such as XML. The structure of the IDB is presented in Appendix D. Also some useful queries are included in Section D.3 which shows usefulness of our IDB.

3.6 Data Sets

Each of our databases consists of three data sets:

- Training Set

  Every recognition system needs some samples for learning the patterns of the classes it will be recognizing. This data set serves as the Training Set. To catch as many writing styles as possible, usually most of the samples are assigned to the Training Set. In our databases almost 60% of the images are assigned to this data set.

- Testing Set

  This set of images is used for testing the power of the recognition system. Because the images in this set are considered as unseen images and are totally different from the ones in the Training Set, they can be used as a criterion for the power of the recognition system in test. Almost 30% of the images are assigned to this data set

- Verifying Set

  For a research to be as close as possible to a real situation, it should be tested against unseen data. Therefore, we need an additional data set for tuning the recognition system before applying it to the testing data set. A researcher might test a designed recognition system using the Verifying Set over and over again to adjust classifier parameters, or to change features in order to get the best results possible before running it on the Testing Set. Almost 10% of the images are assigned to this data set.

3.7 Writers

From different ages, job categories, and genders, 175 Farsi speakers were selected to fill out our two data-entry forms. We tried to cover a broad type of people in different situations including high school students and teachers, university students and professors, computer technicians, business men or women, housewives, engineers, etc.

For each set of forms (Form 1 or Form 2) 105 writers (60%) were assigned to the Training Set, 20 writers (10% approximately) to the Verifying Set, and 50 writers (30% approximately) to the Testing Set. Table 5 shows the statistics for the writers of each data set. Because the target databases of Form 1, and Form 2 were totally different, we were able to treat each set of forms independently. More information about the databases included in each form is available in Section 2.2.

Table 5 Number of writers of each data set

	Training Set	Verifying Set	Testing Set	Total
Writers	**105**	**20**	**50**	**175**

3.8 Extracting image of fields

The process of extracting images of fields from scanned forms can be described in the following steps:

- Loading the form template and the scanned image into the memory.

- Finding the edge identifier marks and then scaling (and if necessary rotating) the template for matching it to the scanned form. The process is described in Section 3.9.

- Detecting the form identifier marks on the scanned form, and checking if they match the template. If not, the image should be skipped.

- Extracting the field images based on the template and saving them using the proper filenames to their matching databases, and inserting a record of information related to the image in the IDB.

3.9 Matching a form template to the scanned image

A simple algorithm was used for finding the edge identifier marks. No elaborate algorithm was needed. The program looked at 300x300 pixel regions at each corner. Scanning vertically from the image's corner, to the center of the image, looking for a 20x20 black square. Figure 20 shows the regions. In 300 dpi scans, the size of the edge identifier marks is usually 30x30 pixels but in this case more precision was not needed; additionally, images could be rotated, and choosing a smaller size (20x20) helped to increase the chance of finding the corner marks. After finding the corners, the program was able to scale the designed template (or rotate it if necessary) to match and fit the boundaries of the scanned image.

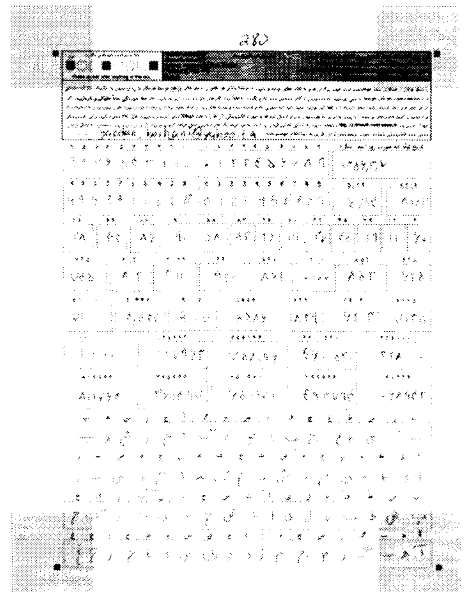


Figure 20 Regions where the program looks for edge identifier marks

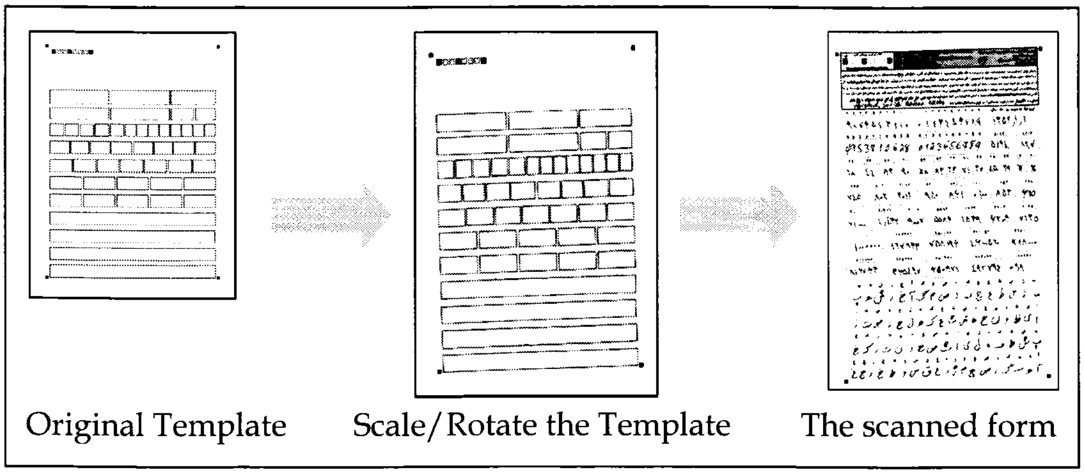


Figure 21 Preparing the template and applying it to the scanned image

After matching the edge identifiers of the scanned image to the form template, all the fields in the template were matched to their proper places on the scanned image and the program was then ready to extract the images from the scanned form. Figure 21 illustrates this process.

3.10 Extracting images of fields

All of the images extracted from their respective forms were saved to the same data set. The data set to which an image belonged, along with additional information of each individual image, were inserted as a record into a Microsoft® Access™ database. The record included path to the image file relative to the base folder, a tagged label, the number of characters in the image, the number of words in the image, the type of content (numerical, date, legal amount or letter), etc. By querying this information, future researchers will easily find the proper set of images that they would like to research. Samples of the records in this database are presented in Appendix D.

To save the images, a directory structure was designed with a file naming convention. The naming convention gave each image a unique filename. The uniqueness of each filename enables a researchers to copy all the images into one folder, if they desire so. The naming convention and the directory structure of the databases are described in Appendix C.

3.11 Segmentation

After extracting the images of the fields, a segmentation algorithm was run on images of the numerical strings, and on Farsi letters, to extract images of isolated digits, and letters. The segmentation algorithm as shown in Figure 22 used vertical white spaces to separate the characters.

Figure 22 Segmentation of a numerical string

3.12 Normalizing the number of isolated digits

Because separating all of the digits was not possible (due to connectivity), writers did not participate equally in the database for each digit. For this reason, the number of digits extracted for each digit varies from 1890 to 2322. Therefore, for normalize the database of isolated digits we decided to include only 1800 samples per digit (1100 samples in the Training Set, 200 samples in the Verifying Set, and 500 samples in the Testing Set) in the database. In doing so, some of the digits that were written by those writers that had the most participation were randomly removed. This was only done on the isolated digits database. The algorithm used is shown in Figure 23. In this algorithm, every time a digit is removed, a different writer would be the most participating writer. This procedure was executed for each digit in each data set separately.

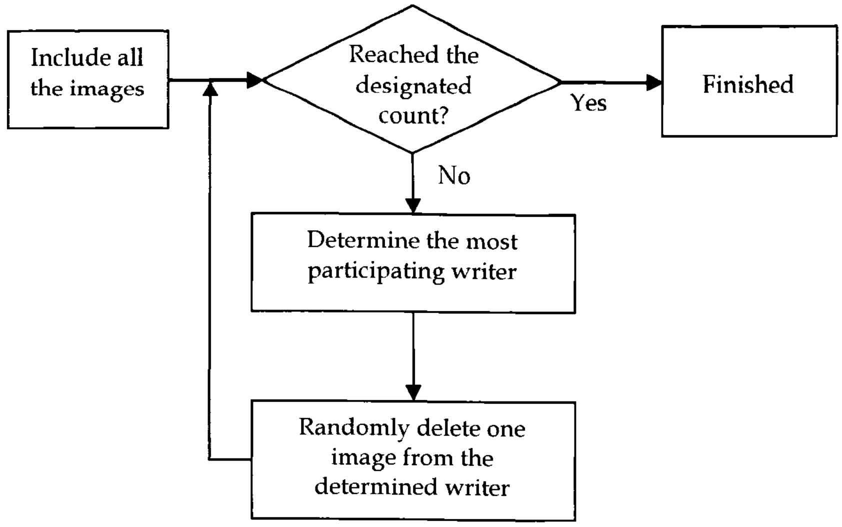


Figure 23 Algorithm of normalizing the writer participation for each digit

3.13 Labeling / Verification

Each field had already been labeled in the template designed for the forms except for two free fields (one was the date field in Form 1, and the other one was the free legal amount in Form 2); therefore, the program was able to automatically label the images at the time of extracting them. Correspondingly, all of the images extracted by segmenting the fields, were automatically labeled. The two free fields were manually labeled. After labeling images, images in all databases were manually verified to ensure correct labeling.

3.14 Statistics

The statistics of the databases including the total number of images, the number of classes, and the number of images in each data set are shown in Table 6.

Table 6 Statistics of the Farsi databases

Database	Total	Classes	Training Set	Verifying Set	Testing Set
Writers	175		105	20	50
Farsi Isolated Digits	**18000**	**10**	11000	2000	5000

Database		Total	Classes	Training Set	Verifying Set	Testing Set
Writers		175		105	20	50
Farsi Isolated Letters		**11900**	**34**	7140	1360	3400
Farsi Numerical Strings		**7350**	**42**	4410	840	2100
Farsi Dates		**175**	**175**	105	20	50
English Digits		**3500**	**10**	2100	400	1000
Legal Amounts	Words	**7875**	**45**	4725	900	2250
	Test Strings	**700**	**169**	420	80	200

In the next chapter we will describe the recognition system we created for recognizing isolated digits.

CHAPTER 4

Recognition of Farsi Digits

In order to show the applications and the usefulness of our databases, we conducted some recognition experiments on our handwritten isolated Farsi digits. This experiment consisted of designing the features used for describing the digits, and then using Support Vector Machines (SVM) to recognize them.

4.1 Feature Extraction

For our recognition system we used the features presented in [12]. In total, eight features were extracted for each image as follows:

- Outer profiles from four directions (four features).
- Horizontal and vertical crossing counts (two features).
- Horizontal and vertical projected histograms (two features).

Each feature, after extraction, was normalized into an 8-dimensional vector, and then the combination of all these vectors created a 64-dimensional feature vector for any particular image.

For resampling each feature into an 8-member array, we used a simple linear interpolation for up-sampling and an averaging for down-sampling the feature arrays when necessary. This normalization procedure made the features invariant to the image stretch in the orientation of the features [21]. In the following sections, details of each feature will be described.

4.2 Outer profiles

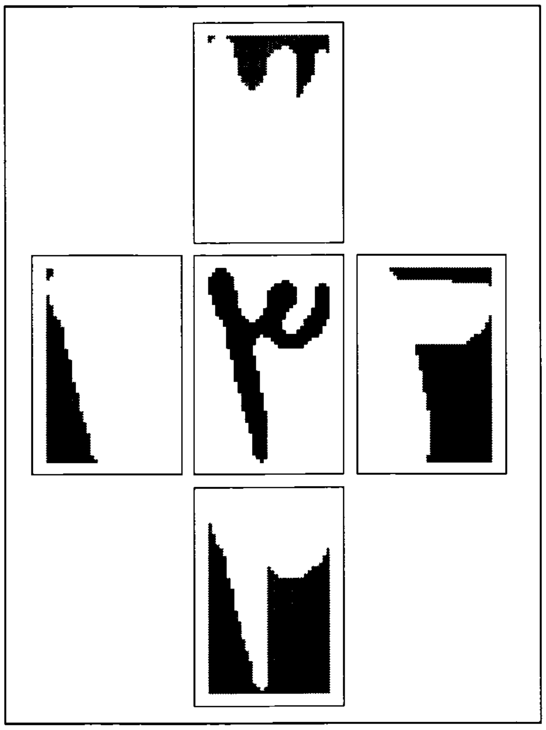


Figure 24 Outer profiles of a sample of Farsi digit "3" from four directions

The outer profile of an image in the left direction can be extracted by scanning the entire image from top to bottom (y-coordinate), and for each row, the first non-empty pixel is located (from the left), and the x-coordinate of the pixel is placed into an array which will then give us the left outer profiles. For extracting outer profiles in the other directions, we rotate the image by 90 degrees, three times, and repeat the same operation again each time. This will give us four outer profiles [21]. Figure 24 shows the outer profiles for a sample of the Farsi digit "3".

In order to make the outer profile feature invariant to the image stretch in the orientation that is perpendicular to the orientation of the profile, each member of the profile vectors was divided by the length of the image in the direction perpendicular to the orientation of the profile.

Figure 25 shows the reconstruction of samples of the Farsi digits "0" to "9" using their outer profiles. From this figure, it is obvious that the outer profile features can represent most of the shape information for the samples; however, they represent mostly the outer shape of the images only, and the inner shapes may be neglected. To consider the inner shape of the images, two complementary features were added to the set of features: crossing counts and projection histograms.

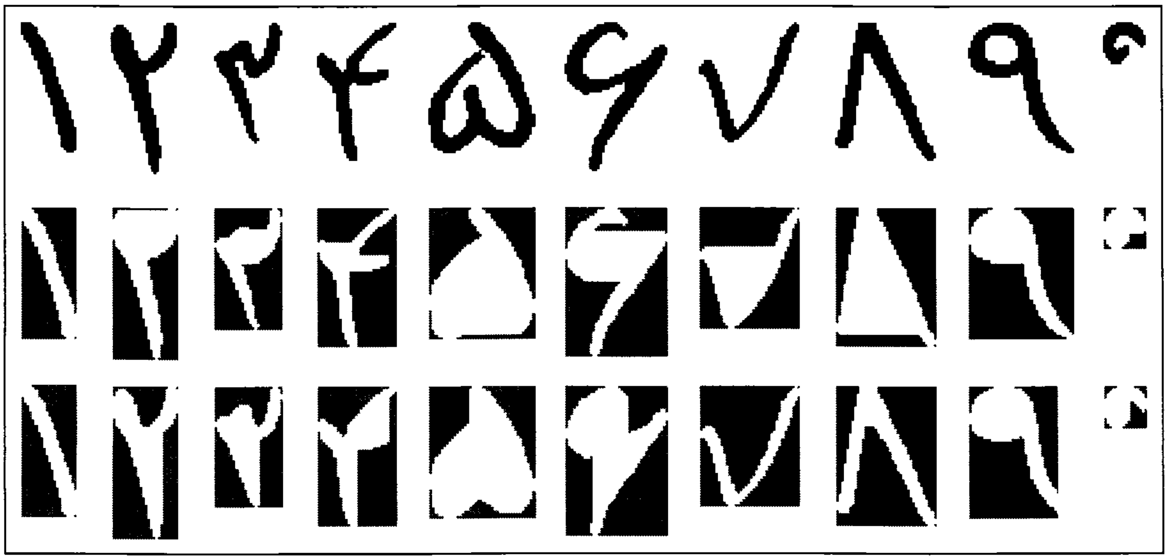


Figure 25 Reconstructing digit images using the extracted outer profiles. The top, middle and bottom rows consist of the original digits, their reconstruction using left and right outer profiles, and their reconstruction using up and down profiles respectively.

4.3 Crossing Counts

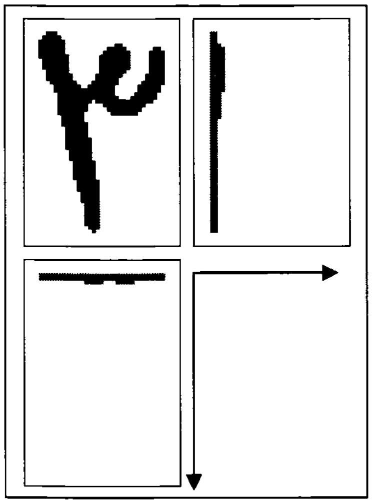


Figure 26 Samples of the crossing count features from two orientations for Farsi digit "3"

Crossing count features can be extracted horizontally and vertically. The horizontal crossing count is formed by finding the number of connected black segments in each column of the image and putting them into an array, which we call a horizontal crossing count vector. This vector is resampled later to form a vector of size 8 as described in Section 4.1. The vertical vector is extracted in the same way, after rotating the image by 90 degrees. Figure 26 shows examples of the crossing count features for a sample of handwritten Farsi digit "3" (before resampling).

4.4 Projection Histogram

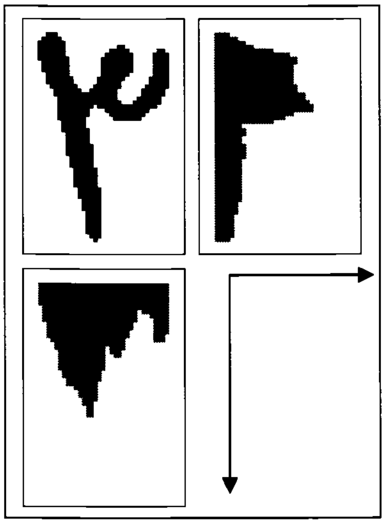


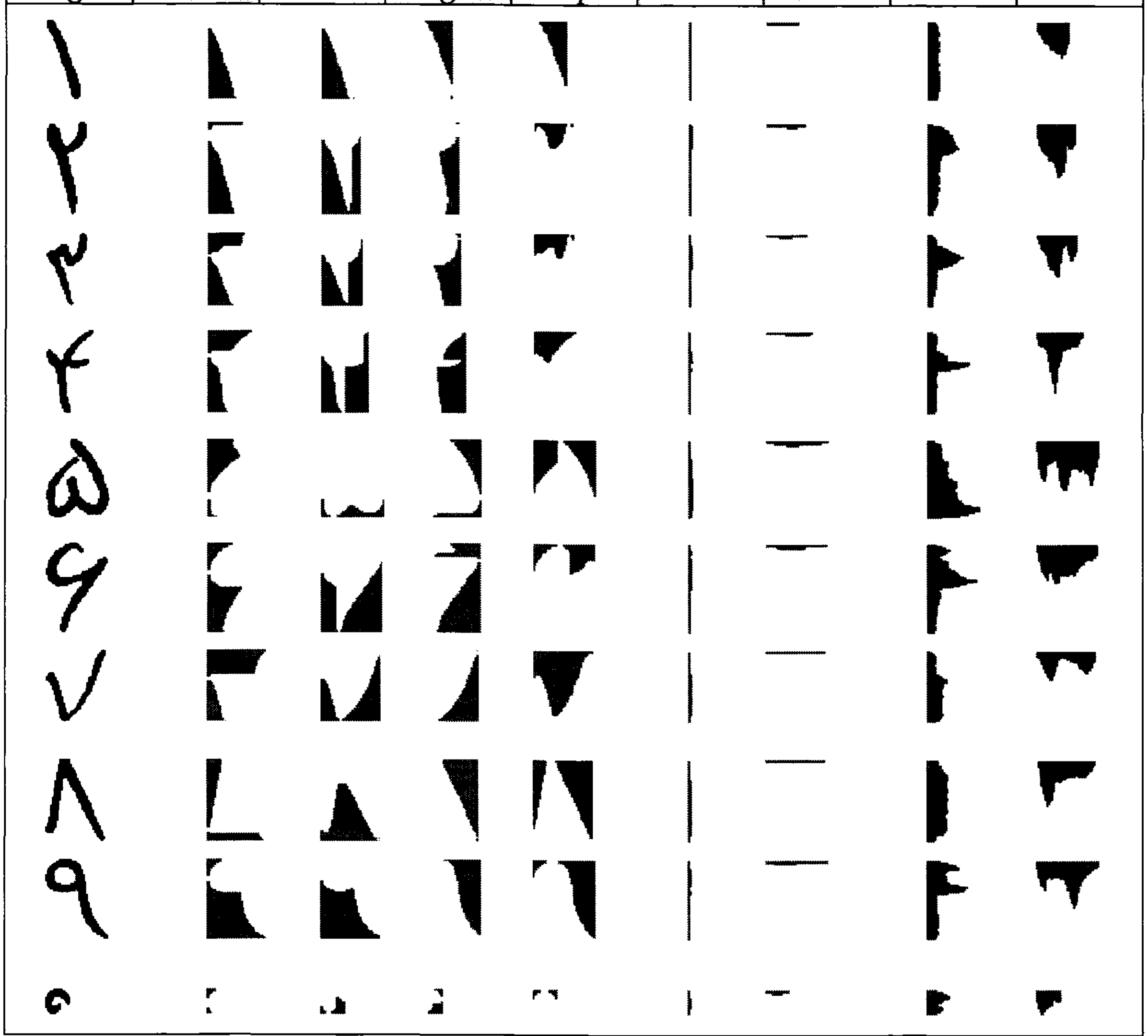
Figure 27 Samples of the projection histogram feature

Projection histograms can also be extracted horizontally and vertically. To extract the horizontal projection histogram of an image, the number of black pixels in each column of the image is put into an array which is called the horizontal histogram vector, and then the array gets resampled to a vector of size 8 as described before. The vertical projection histogram feature vector can be extracted by rotating the image by 90 degrees and applying the same algorithm to the rotated image.

Projection histogram vectors are also divided by the average value of the vector. This ensures that the extracted features are invariant to the stretch in the orientation that is perpendicular to the orientation of the histogram, and also to the pen thickness. Figure 27 shows projection histograms extracted from a sample of the handwritten Farsi digit "3" and Table 7 shows all the 8 features (before resampling) for 10 samples of the handwritten Farsi digits "0" to "9."

Table 7 Features extracted for samples of Farsi digits

	Outer Profiles				Crossing Counts		Projection Histograms	
Digit	Left	Down	Right	Up	Vert.	Horiz.	Vert.	Horiz.



4.5 Classification

Support Vector Machines (SVMs) [22] were used for classification [22]and are briefly described in Appendix F. LIBSVM software [23], an implementation of a multi-class SVM classifier, was used for classification. Before testing the classifier on the Testing Set, the SVM kernel, and value of each kernel parameter had to be determined. In order to get the best results, the experiment was repeated using these two popular SVM kernels:

- Polynomial Kernel
- Radial Basis Function (RBF) Kernel

There is no written rule for determining the best values of kernel parameters and they are usually determined by assigning different values to them, and then deciding which values to use, based on the classifier output. Therefore, for each parameter of the kernel, we defined a set with 10 or more values. Using each of the values in the set, one by one, the classifier was trained by the Training Set, and then recognition rate was calculated using the Verifying Set. The parameter values that generated the best recognition rate on the Verifying Set were selected as the best values for the target kernel. Table 8 shows the set of values that we examined, and the best chosen value for each kernel parameter.

The Verifying Set as already described in Section 3.6 is used here only for tuning the classifier. This enables us to simulate a real-world situation by later testing the classifier on the Testing Set, which contains unseen data.

Table 8 Parameter ranges used for tuning SVM kernels

Kernel	Parameter	Set of Values	Best Value
Polynomial	C	$\{ i_n \mid n \in \mathrm{IN}, i_0 = 1, i_n \leq 101, i_{n+1} = i_n + 10 \}$	**1**
	γ	$\{ i_n \mid n \in \mathrm{IN}, i_0 = 0.05, i_n \leq 1.05, i_{n+1} = i_n + 0.05 \}$	**0.35**
	Degree	$\{ i_n \mid n \in \mathrm{IN}, i_0 = 1, i \leq 4, i_{n+1} = i_n + 1 \}$	**3**
RBF	C	$\{ 2^{i_n} \mid n \in \mathrm{IN}, i_0 = -5, i_n \leq 15, i_{n+1} = i_n + 0.5 \}$	**$2^{3.5}$**
	γ	$\{ 2^{i_n} \mid n \in \mathrm{IN}, i_0 = -14, i_n \leq 0, i_{n+1} = i_n + 0.5 \}$	**$2^{-4.5}$**

4.6 Adjusting the classifier for digit Zero ("0")

The character zero has special characteristics that have been described in Section 2.4. The most important quality of this digit is its height as described before, which is about one fifth of other digits. This quality has a special effect on the probabilities that the SVM classifier calculates for images of Zero. The small size of the images makes it hard for the recognizer to distinguish Zeros from other images, and therefore, as experienced on the Training and Verifying Sets, the probabilities that are generated are very low when it is predicted correctly, and it is high when it is not predicted correctly. Although this might not affect the recognition process normally, it adds difficulty to the rejection methods.

To correct this behavior, we added two steps to our classification process: height classifier, and probability adjustor. Height classifier is added right before involving SVM classifier and it simply classifies the input image as Zero if its height is less than 20 pixels. The value of 20 was extracted by finding out the minimum height of all the images other than Zero in the Training Set and

Verifying Set. The probability adjustor is the step added after the SVM classifier generates probabilities of all the classes for the input image. In this step, if the class with the highest probability is Zero, the probability is adjusted using this formula: $p = p + \text{sgn}(p - 0.4) \times 0.4$ where $\text{sgn}(x) = |x| / x, x \neq 0$. This is a simple formula that pulls up the low values, and pushes down the high values of probability in order to correct the behavior of the SVM classifier. Figure 28 shows the entire classification process.

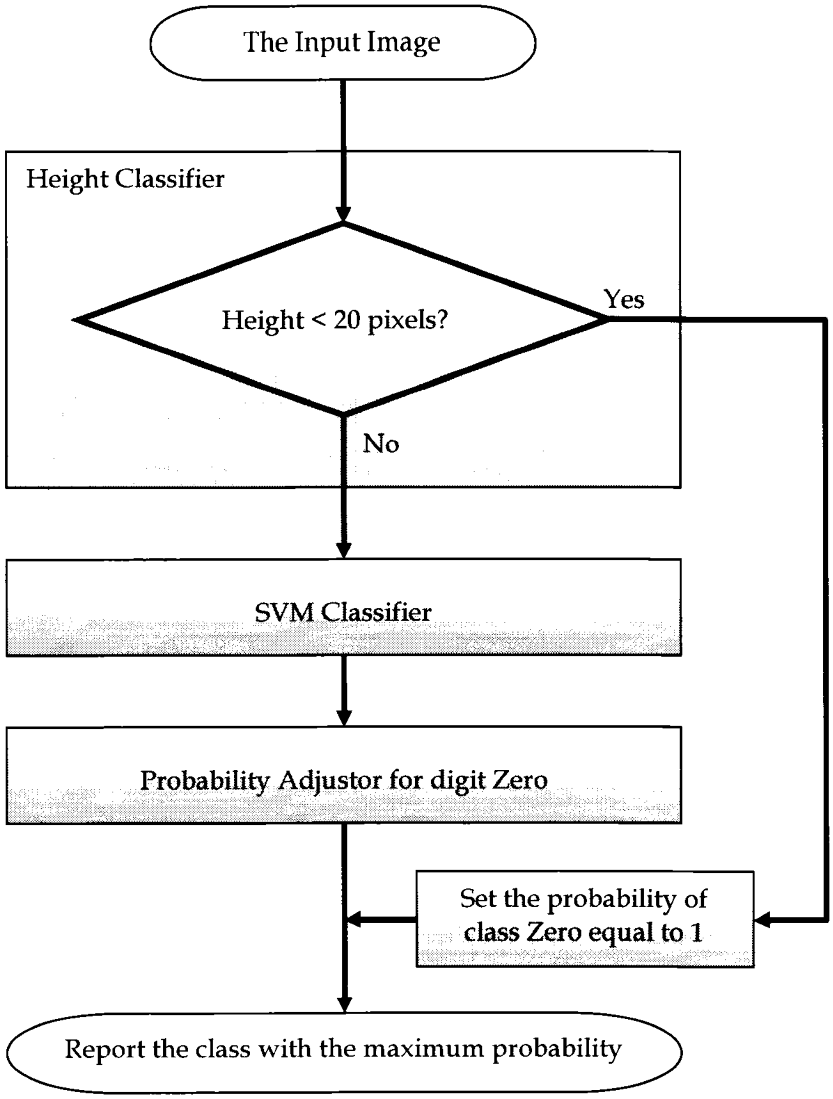


Figure 28 The classification process

4.7 Results before applying the rejection

Table 9 shows the overall results of our experiment on the Testing Set. As presented in this table, the best recognition rate achieved was 97.36%, and the training error was 0.69%.

Table 9 The overall results of the experiment

SVM Kernel	Support Vectors	Recognition Rate	Training Error
Polynomial	1497	96.68%	0.09%
RBF	1301	**97.36%**	0.69%

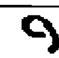
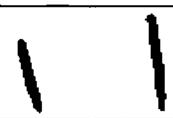
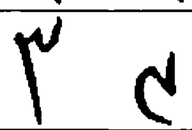
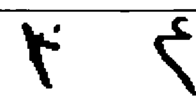
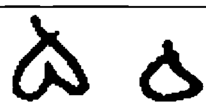
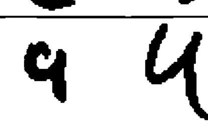
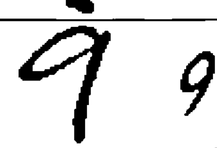
The features that we used for our recognition system are partly similar to those used in [12] and [17] (but the classification process is completely different); so, we tried to compare our results with the works mentioned in Table 10. It should be noted that the comparison is not accurate because the database used by each research was different. This practically supports the idea of creating a common database to be made available to researchers.

Table 10 Comparison of our results with other works

	Our Results	Results of [12]	Results of [17]
Training Set (# of samples)	11000	4500	7390
Verifying Set (# of samples)	2000	-	-
Testing Set (# of samples)	5000	3600	3035
Number of Support Vectors	1301	629	-
Training Error	**0.69%**	0.00%	0.24%
Recognition Rate	**97.36%**	99.44%	94.14%

Some typical examples of errors are shown in Table 11. The confusion matrices of the experiment are shown in Tables 14, 15, and 16. From these matrices it is easy to say that most misclassifications occur when the shape of the digits are close. Like 2 and 3, 0 and 5, or 6 and 9.

Table 11 Typical examples of misclassifications

Digit	Classified Correctly	Misclassified	
		Predicted As	Samples
0		1	
		5	
		9	
1		0	
3		2	
4		2	
		6	
5		0	
6		4	
		9	
9		1	
		6	

4.8 Rejection Strategy

In practice, other criteria than minimum classification error can be important. These criteria include the use of class dependent misclassification costs and Neyman-Pearson style classification [24]. The use of a reject class can help to reduce the misclassification rate in tasks where exceptional handling, for instance, by a human expert, of particularly ambiguous cases is feasible. The decision to reject a pattern x and to handle it separately can be based on its probability to be misclassified which for the Bayes rule is $\varepsilon(x) = 1 - \max_{j=1,\dots,c} q_j(x)$, where c is number of classes, and $q_j(x)$ is the posteriori probability of class j given the input pattern x. The highest misclassification probability occurs when the posterior probabilities $q_j(x)$ are equal and then $\varepsilon(x) = 1 - 1/c$. Consequently, a rejection threshold $0 \leq \theta \leq 1 - 1/c$ can be selected, and x rejected if $\varepsilon(x) > \theta$.

Table 12 Rejection thresholds of each class

Class	Rejection Threshold (θ)
0	0.40
1	0.56
2	0.64
3	0.62
4	0.66
5	0.00
6	0.68
7	0.46
8	0.38
9	0.50

For selecting a rejection threshold for each class, we conducted an experiment. In this experiment, the threshold of each class was set from 0.01 to 0.9 with steps of 0.02, and for each step, the rates of recognition, error, and rejection were recorded in a table. Then from the table, the least threshold that gave the best result (the rejection rate <= 3%, and the error rate <= 1%) was selected for each class except zero. The threshold for Zero was set to 0.4 that is the factor by which the probability calculated by the classifier adjusted (described in Section 4.6). Table 12 presents the selected values of θ for each class of isolated digits.

In Appendix G, the details of the table constructed for rejections and the diagrams of the relation of rejection rate to error rate for each class are all presented. Results after applying the rejection strategy are shown in the Table 13.

Table 13 Results of the classification before and after applying rejections using RBF kernel

	Recognition Rate	Rejection	Error
Without Rejection	97.36%	-	2.64%
With Rejections	**95.60%**	2.94%	1.46%

4.9 Discussion

Tables 14, 15, and 16 show the confusion matrices of Testing, Training, and Verifying Sets respectively. These results are shown before and after applying rejections. Each row in these tables shows how an isolated digit was classified.

In these confusion matrices, we see that the rejection method helped to decrease the error rate; however, in some cases still a lot of misclassifications can be seen. While reviewing the misclassified samples that could not be rejected (samples are included in Table 11), one can see that the inability to recognize or reject the samples depends on how the sample's shape is similar to the digit it is recognized as. For example (0, 1), (6, 9), and (2, 3, 4) are the classes with the most misclassifications.

Table 14 Confusion matrix of the Testing Set using Radial kernel

Label ↓		Classification									
		0	1	2	3	4	5	6	7	8	9
0	BR*	**489**	4	1	2		2	1		1	
	AR**	**488**	2		1		1				
1	BR	17	**474**	1		2		2	3		1
	AR	14	**469**								1
2	BR		1	**490**	3	5			1		
	AR		1	**463**	1	5					
3	BR			15	**474**	9	2				
	AR			9	**451**	4	1				
4	BR			4	3	**492**		1			
	AR			1	2	**485**		1			
5	BR	8					**492**				
	AR	7					**492**				
6	BR	4	2	5	1	4	2	**472**			10
	AR	4	2			1	1	**450**			8
7	BR		1						**499**		
	AR		1						**498**		
8	BR								1	**499**	
	AR									**498**	
9	BR							10		3	**487**
	AR							2		3	**486**

* BR: Before Rejection, ** AR: After Rejection

Table 15 Confusion matrix of the Training Set using Radial kernel

Label ↓		Classification									
		0	1	2	3	4	5	6	7	8	9
0	BR*	**1074**	17				6	1			2
	AR**	**1071**	16				4				2
1	BR	16	**1080**					2			2
	AR	9	**1078**					1			2
2	BR			**1096**	3	1					
	AR			**1083**	2	1					
3	BR			7	**1093**						
	AR			1	**1090**						
4	BR			1		**1099**					
	AR					**1097**					
5	BR	9					**1091**				
	AR	8					**1088**				
6	BR					1		**1098**			1
	AR					1		**1091**			
7	BR								**1100**		
	AR								**1100**		
8	BR									**1100**	
	AR									**1100**	
9	BR		4					3			**1093**
	AR		4					1			**1093**

* BR: Before Rejection, ** AR: After Rejection

Table 16 Confusion matrix of the Verifying Set using Radial kernel

Label ↓		Classification									
		0	1	2	3	4	5	6	7	8	9
0	BR*	**192**	3		1	1	3				
	AR**	**192**	1		1		2				
1	BR	5	**194**			1					
	AR	4	**193**								
2	BR		1	**194**		2		3			
	AR		1	**182**		1		2			
3	BR			10	**183**	6		1			
	AR			3	**179**	4					
4	BR			3		**196**					1
	AR					**194**					1
5	BR						**200**				
	AR						**199**				
6	BR		1			9		**188**	1		1
	AR					8		**182**	1		1
7	BR		1	1				1	**197**		
	AR								**197**		
8	BR							1		**199**	
	AR									**198**	
9	BR					1	1	5			**193**
	AR							2			**189**

* BR: Before Rejection, ** AR: After Rejection

Figure 29 shows all the samples that are misclassified in the Testing Set. Below each sample, the label of the image, and what the sample is recognized as are shown respectively. For example 6~9 means that the image is a sample of the digit 6, but recognized as 9. In this figure the samples that are rejected in the rejection process, are tagged with gray. It can be noticed in these images that most of them share qualities of the class they are in, and the class they have been recognized as which sometimes causes even a human to make the same mistake. Because we use statistical features, some of the structural properties of the image are lost. Therefore, perhaps adding some structural features will help recognizing those images.

Figure 29 All the samples that are misclassified in the Testing Set. The samples in gray are rejected in the rejection process. Under each image, the first digit is the label of the sample, and the second digit is the prediction.

CHAPTER 5

Conclusion and Future Work

The major contribution of this work is the design and development of six new standard databases, consisting of handwritten Farsi numerical strings, isolated digits, isolated letters, legal amounts, dates, and a small set of English digits which may serve as a basis for future research in offline Farsi handwritten recognition. Creation of these databases is an important step towards standardization of the research on Farsi OCR, since comparing the results of a research with results of other works on the same database is an important part of the development and the evaluation of a method.

All of the produced databases contain both binary and grayscale versions of the images, allowing for future experimentation and comparison with both grayscale and binary preprocessing and recognition techniques.

The produced databases can be adopted easily for use in research or different applications including form processing, postal code recognition, car plate recognition, bank-cheques processing, OCR applications used in Personal Digital Assistants (PDA), and many more.

These databases are available to the research community upon request to the Center of Pattern Recognition and Machine Intelligence (CENPARMI) of Concordia University (http://www.cenparmi.concordia.ca).

In the future, more databases may be added to our set such as:

- Words and sub-words.
- Sentences and Texts.
- Real bank-cheques samples.
- Addresses and Postal codes.
- Real samples of addresses on mailing envelopes.

In this work, also, a recognition system was developed to recognize isolated Farsi digits. The isolated digits database that had been produced was used for training, adjustment, and testing of this system. This system used an SVM classifier with both Polynomial and RBF kernels and the best result was gotten using RBF kernel which produced a recognition rate of 97.36%. To improve the errors of the classifier a rejection strategy was developed that could bring down the error rate by 1.18%.

Our recognition system can be enhanced in the future by applying clustering techniques. This is especially important since some of the isolated digits in Farsi can be written in totally different styles. Another possible enhancement would be extracting some extra features and adding them to our set of features. These new features should be used to illustrate differences between misclassified digits.

We are also planning to conduct experiments on other databases introduced in this work.

References

[1] S. Mori, C. Y. Suen and K. Yamamoto, "Historical review of OCR research and development," *Proceedings of the IEEE*, 1992, Volume 80, pp. 1029-1058.

[2] R. Legault, "Unconstrained Handwritten Numeral Recognition: A contribution towards matching human performance," *A Thesis in the Department of Computer Science*, Concordia University, 1997.

[3] I. Guyon, R. Haralick, J. Hull, and I. Phillips, "Database and benchmarking," In H. Bunke and P. Wang, editors, *Handbook of Character Recognition and Document image Analysis*, World Scientific, 1997, Chapter 30, pp. 779–799.

[4] R. Wilkinson, J. Geist, S. Janet, P. Grother, C. Burges, R. Creecy, B. Hammond, J. Hull, N. Larsen, T. Vogl, and C. Wilson. *The first census optical character recognition systems conf. #NISTIR 4912*, The U.S. Bureau of Census and the National Institute of Standards and Technology, Gaithersburg, MD, 1992.

[5] J. Hull, "A database for handwritten text recognition research," *IEEE Trans. on Pattern Analysis and Machine Intelligence*, May 1994, Volume 16, Issue 5, pp. 550–554.

[6] C. Y. Suen, C. Nadal, R. Legault, T. Mai, and L. Lam, "Computer recognition of unconstrained handwritten numerals," *Proc. of the IEEE*, 1992, Volume 7, Issue 80, Pages 1162–1180.

[7] I. Guyon, L. Schomaker, R. Plamondon, M. Liberman, and S. Janet, "Unipen project of on-line data exchange and benchmarks," *Proc. of the 12th IAPR Int. Conf on Pattern Recognition*, Jerusalem, Israel, Oct. 1994, pp. 29–33.

[8] Y. Al-Ohali, M. Cheriet, and C.Y. Suen, "Databases for recognition of handwritten Arabic checks," *Proceedings of the Seventh Int. Workshop on Frontiers in Handwritten Recognition*, Sept. 2000, pp. 601-606.

[9] M. Pechwitz, S. Snoussi Maddouri, V. Märgner, N. Ellouze , H. Amiri, "IFN/ENIT database of handwritten Arabic words", *Proceedings of Colloque International Francophone sur l'Écrit et le Document (CIFE)*, 2002, pp. 129-136.

[10] F. Jelinek, "Self-organized language modeling for speech recognition," In

A. Waibel and K.-F. Lee, editors, *Readings in Speech Recognition*, Morgan Kaufmann Publishers Inc., 1990, pp. 450–506.

[11] D. Kim, Y. Hwang, S. Park, E. Kim, S. Paek, and S. Bang, "Handwritten Korean character image database PE92," *Proceedings of the Second Int. Conference on Document Analysis and Recognition*, 1993, pp. 470–473.

[12] M. H. S. Shahreza, K. Faez, and A. Khotanzad, "Recognition of handwritten Persian/Arabic numerals by shadow coding and an edited probabilistic neural network," *Proceedings of the International Conference on Image Processing*, Volume 3, 1995, pp. 436–439.

[13] H. Soltanzadeh, and M. Rahmati, "Recognition of Persian handwritten digits using image profiles of multiple orientations," *Pattern Recognition Letters*, 2004, Volume 25, pp. 1569–1576.

[14] S. Mozaffari, K. Faez, H.R. Kanan, "Recognition of isolated handwritten Farsi/Arabic alphanumeric using fractal codes," *6th IEEE Southwest Symposium on Image Analysis and Interpretation*, 2004, pp. 104 - 108.

[15] A. Harifi, and A. Aghagolzadeh, "A new pattern for handwritten Persian/Arabic digit recognition," *International Journal Of Information Technology*, 2004, Volume 1, Number 4, pp. 293–296.

[16] F. N. Said, R. A. Yacoub, C. Y. Suen, "Recognition of English and Arabic numerals using a dynamic number of hidden neurons," *Proceedings of the Fifth International Conference on Document Analysis and Recognition*, 1999, pp. 237–240.

[17] J. Sadri, C. Y. Suen, T. D. Bui, "Application of Support Vector Machines for recognition of handwritten Arabic/Persian digits," *Proceedings of the Second Conference on Machine Vision and Image Processing & Applications (MVIP2003)* , Tehran, Iran, Feb. 2003, Volume 1, pp. 300-307.

[18] C. Lilley, "PNG (Portable Network Graphics)," *The World Wide Web Consortium (W3C)*, URL: `http://www.w3.org/Graphics/PNG/`

[19] N. Otsu, "A thresholding selection method from gray-level histogram," *IEEE Transactions on Systems, Man, and Cybernetic*, 1979, Volume 9, pp. 62-66.

[20] J. S. Lim, "Two-dimensional signal and image processing," Englewood Cliffs, editor, Prentice Hall, USA, 1990, pp. 469-476.

[21] D. Trier, A.K. Jain, T. Taxt, "Feature extraction methods for character recognition - a survey," *Pattern Recognition*, 1996, Volume 29, pp. 641-662.

[22] C. J. C. Burges, "A tutorial on support vector machines for pattern recognition," *Data Mining and Knowledge Discovery*, 1998, Volume 2, pp. 121-167.

[23] C. C. Chang, Chih-Jen Lin, "LIBSVM: a library for support vector machines," URL: `http://www.csie.ntu.edu.tw/~cjlin/libsvm`

[24] T. Y. Young and T. W. Calvert, "Classification, Estimation and Pattern Recognition," *New York: Elsevier Science Publishers*, 1974.

Appendix A List of fields in the data entry forms

A.1 Form 1 – Numbers, Letters, and Dates

Field No.	Data Entry Field	English Equivalent
0001	Free Date Field	-
0002	٠١٢٣۴۵۶٧٨٩	0123456789
0003	٩٨٧۶۵۴٣٢١٠	9876543210
0004	٨٢/٧	82.7
0005	۵/٩۴	5.94
0006	0123456789	0123456789
0007	4953710628	4953710628
0008	۶٠	60
0009	١٢	12
0010	٢٩	29
0011	۴۵	45
0012	٣٧	37
0013	٧١	71
0014	٢۶	26
0015	٨٣	83
0016	۵٨	58
0017	٩٠	90
0018	٨۶	86
0019	۴۴	44
0020	٢٨	28
0021	۶٢۵	625
0022	٨۵٣	853
0023	٠١٠٠	0100

Field No.	Data Entry Field	English Equivalent
0024	۸۶۱	861
0025	۹۴۰	940
0026	۳۰۱۲	3012
0027	۸۰۲	802
0028	۷۴۵	745
0029	۷۱۳۵	7135
0030	۶۲۰۳	6203
0031	۱۸۳۹	1839
0032	۵۵۸۶	5586
0033	۹۰۰۷	9007
0034	۴/۴۳۲	4.432
0035	۷۱۰۰۰	71000
0036	۳۲۸۰۰۰	328000
0037	۴۶۰۰۵۲۰	4600520
0038	۷۵۸۱۹۶	758196
0039	۱۲۷۹۶۳	127963
0040	۱۰۰۰۰۰۰	1000000
0041	۰۶۸۹۴۳	068943
0042	۴۹۳۷۹۴	493794
0043	۶۵۰۹۷۱	650971
0044	۳۶۵۴۹۷	365497
0045	۸۱۲۷۶۳	812763
0046	ب ژ س ط ع چ ف د ض م گ آ خ ر ش ه پ	-
0047	ا ی ظ و ن ح ه ق ث غ ک هـ ل ج ذ ص ت ز	-
0048	پ ش ظ ف ه ل ی ا ث ض ح ذ ن ت ر ک خ	-
0049	آ هـ ب گ ز ص چ م ژ د ع ق س و ط خ ر ج غ	-

A.2 Form 2 - Legal amounts

Field No.	Data Entry Field	English Equivalent
0050	یک	Yek (One)
0051	دو	Do (Two)
0052	سه	She (Three)
0053	چهار	Chahaar (Four)
0054	پنج	Panj (Five)
0055	شش	Shesh (Six)
0056	هفت	Haft (Seven)
0057	هشت	Hasht (Eight)
0058	نه	Noh (Nine)
0059	ده	Dah (Ten)
0060	یازده	Yaazdah (Eleven)
0061	دوازده	Davaazdah (Twelve)
0062	سیزده	Sizdah (Thirteen)
0063	چهارده	Chahaardah (Fourteen)
0064	پانزده	Paanzdah (Fifteen)
0065	شانزده	Shaanzdah (Sixteen)
0066	هفده	Hefdah (Seventeen)
0067	هجده	Hejdah (Eighteen)
0068	نوزده	Noozdah (Nineteen)
0069	بیست	Beest (Twenty)
0070	سی	See (Thirty)
0071	چهل	Chehel (Forty)
0072	پنجاه	Panjaah (Fifty)
0073	شصت	Shasst (Sixty)

Field No.	Data Entry Field	English Equivalent
0074	هفتاد	Haftad (Seventy)
0075	هشتاد	Hashtaad (Eighty)
0076	نود	Navad (Ninety)
0077	صد	Sad (Hundred)
0078	يكصد	Yeksad (One hundred)
0079	دويست	Deveesst (Two hundred)
0080	سيصد	Seesad (Three hundred)
0081	چهارصد	Shahaarsad (Four hundred0
0082	پانصد	Paansad (Five hundred)
0083	ششصد	Sheshsad (Six hundred)
0084	هفتصد	Haftsad (Seven hundred)
0085	هشتصد	Hashtsad (Eight hundred)
0086	نهصد	Nohsad (Nine hundred)
0087	هزار	Hezaar (Thousand)
0088	يكهزار	Yekhezaar (One thousand)
0089	ميليون	Million (Million)
0090	ميليارد	Milliard (Billion)
0091	ريال	Rial (Rial)
0092	تومان	Toumaan (Toumaan)
0093	تمام	Tamaan (Over)
0094	معادل	Moadel (Equal to)
0095	سيصد و شصت هزار ريال	Seesad o shasst hezaar rial (Three hundred and sixty thousand rials)
0096	پانصد و سی و سه ميليون و هفتصد و شش	Paansad o see o se million o haftsad o shesh (Five hundred and thirty three million and seven hundred and six)

Field No.	Data Entry Field	English Equivalent
0097	یکصد و چهل تومان تمام	Yeksad o chehel toumaan tamaam (One hundred and Forty touman over)
0098	Free Legal amount	-

Appendix B List of Farsi letters, digits, and the decimal point

B.1 Farsi Letters

Farsi Letters and their different styles				Name	English Equivalent
Isolated	Terminator	Middle	Starter		
ا	ـا	×	ا	alef	a, aa
آ (ا)	ـآ	×	آ	ā	aa, u
ب	ب	بـ	بـ	be	n
پ	پ	پـ	پـ	pe	p
ت	ت	تـ	تـ	te	t
ث	ث	ثـ	ثـ	s̲e	s
ج	ج	جـ	جـ	jīm	j
چ	چ	چـ	چـ	che	ch
ح	ح	حـ	حـ	he	h
خ	خ	خـ	خـ	khe	kh
د	د	×	×	dāl	d
ذ	ذ	×	×	zāl	z
ر	ر	×	×	re	r
ز	ز	×	×	ze	z
ژ	ژ	×	×	zhe	zh
س	س	سـ	سـ	sīn	s
ش	ش	شـ	شـ	shīn	sh
ص	ص	صـ	صـ	sād	s
ض	ض	ضـ	ضـ	zād	z
ط	ط	طـ	طـ	tā	t
ظ	ظ	ظـ	ظـ	zā	z
ع	ع	ـعـ	عـ	'ain	a, a'
غ	غ	ـغـ	غـ	ghain	gh
ف	ف	فـ	فـ	feh	f
ق	ق	قـ	قـ	ghāf	gh

Farsi Letters and their different styles				Name	English Equivalent
Isolated	Terminator	Middle	Starter		
ک	ـک	ـکـ	کـ	kāf	k
گ	ـگ	ـگـ	گـ	gāf	g
ل	ـل	ـلـ	لـ	lām	l
م	ـم	ـمـ	مـ	mīm	m
ن	ـن	ـنـ	نـ	nūn	n
و	ـو	×	×	vāv	v
ه	ـه	ـهـ	هـ	he	h
ی	ـی	ـیـ	یـ	ye	y

B.2 Farsi Digits

Farsi Digit	Name	English Equivalent
۰	sefr	0
۱	yek	1
۲	do	2
۳	se	3
۴	chahār	4
۵	panj	5
۶	shesh	6
۷	haft	7
۸	hasht	8
۹	noh	9

B.3 Farsi Decimal Point

The Decimal Point	Farsi Name	English Name	English Equivalent
/	momayez	Decimal Point	.

Appendix C Physical Structure of the Image Databases

C.1 File Name Convention

Each image file name consists of 5 sections:

0002_00001_04.PNG

1 2 3 4

Section 1: Four digits which identify the field number related to this. Preceding zeros are used where length of the number is smaller than 4 digits. Fields are numbered from the top right of the form to the bottom left, starting from 0001 and numbers in the second form continue from the numbers in the first form. If a file contains the full image of a form, this section will be identified with four zeros: "0000".

Section 2: Five digits identifying the scanned form related to this image. This number can be used as an identifier for the writer of the handwritten image. Preceding zeros are used where length of the number is smaller than 5 digits. This section is separated from the previous section by an underscore character ("_").

Section 3: A "00" means that the file contains an image of a whole field (or a whole form if section 2 is "0000"); however, it can be "01", "02" or upper, if the file contains an image of only one character, and it means that this image was extracted from the original image of the field by segmentation. Characters are numbered from left to right during the segmentation process.

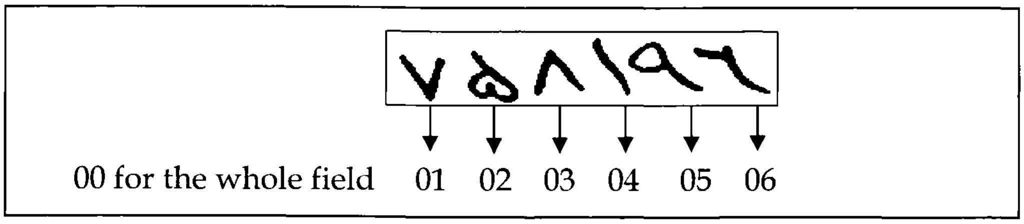


Figure 30Naming convention for the segmented images

The proposed naming convention gives each image a unique filename throughout all the databases. As a result, all of the images can be copied into one folder without being overwritten.

This section is separated from the previous section by an underscore character ("_").

Section 4: ".PNG" is used at all times (which is the standard filename extension for the databases).

C.2 Directory Structure

The physical directory structure of the databases is shown in 0.

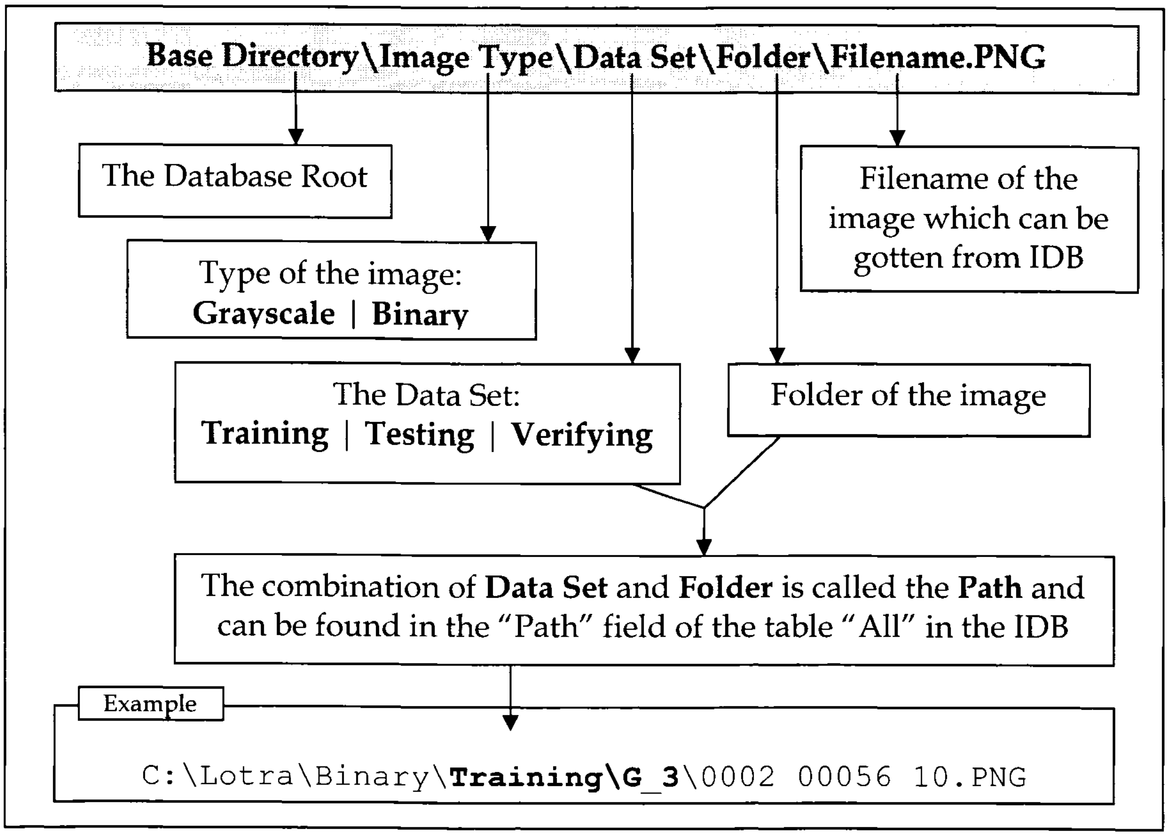


Figure 31 The Directory Structure of the Databases

The expressions used in Figure 31 are described below:

- The Database Root is the path to the folder where the database is installed (e.g. `C:\Farshid`).
- IDB stands for "Information Database" and is our database for information related to every image and is stored as a Microsoft® Access ™ file format. More information is described in Section 3.5 and Appendix D.

Appendix D The Structure of the Information Database (IDB)

Here, the structure of our Information Database (IDB) is presented, which is stored as a Microsoft® Access™ file. For more information, refer to Section 3.5. In the following section, the tables in the IDB are described and the fields in each of them are listed with their data type and purpose.

D.1 Description of the tables and their structure

[FIELDS] Information about fields in the data entry forms.		
Field Name	Field Type	Description
Label	Text(50)	The label of the field. If left empty, means it is a free field and should be labeled manually.
Database	Text(5)	The code of the database that the field belongs to.
Field	Text(4)	The field number. This number related the field to the designed template.
FormID	Number	The ID of the form From the [Forms] table.

[SETS] Information about the data sets.		
Field Name	Field Type	Description
Set	Text(1)	The data set code which is used to identify the data set in other tables.
SetFolder	Text(50)	The folder of this set relative to the database root.
Description	Memo	Description of the set.

[ALL] Information about every individual image in the databases.		
Field Name	Field Type	Description
Filename	Text(21)	The unique filename which identifies the image including the extension
Scan	Text(5)	Page scan number. Logically identifies the writer.
Field	Text(4)	Field number within the page (from top left side of the form). '00' if this record contains the whole page.
Char	Text(2)	Character number within a field (from left to right). '00' if this record contains the whole field or the whole page.
Path	Text(50)	The path to the file including the ending slash. It is relational to the base path. To obtain the full path: Base Path + Path + Filename
Label	Text(50)	Defines the character(s) which are contained in the image of the file. Empty if Type=F
NChars	Number	Length of the image in terms of characters excluding spaces, -1 if Type = F.
NWords	Number	Length of the image in terms of words. Valid only when Type = S, -1 otherwise.
Overlapped	Boolean	Specifies if the image contains at least one pair of overlapped sub sections
Disconnected	Boolean	Specifies if the image contains one or more disconnected character.
Connected	Boolean	Specifies if the image contains at least one pair of connected characters.
Database	Text(5)	The code of the database that the image belongs to.
Set	Text(1)	The set code from the [Sets] table.

[DATABASES] Information about the databases		
Field Name	Field Type	Description
Database	Text(5)	This is the Database code.
IsOneCharacter	Boolean	Determines if images in this database contain only one character. Like isolated digits database.
UniqueLabelPerFolder	Boolean	Determines if all the images have the same label or not. Free fields do not have the same label.
Description	Memo	Description of the database is saved here.

D.2 Samples of the records in the "All" table

Sample of the records in the table [ALL]									
Filename	Scan	Field	Char	Path	Label	NChars	NWords	Database	Set
0002_00001_02.PNG	00001	0002	02	Verifying \G_1	1	**1**	**1**	G	V
0002_00001_03.PNG	00001	0002	03	Verifying \G_2	2	**1**	**1**	G	V
0003_00001_01.PNG	00001	0003	01	Verifying \G_9	9	**1**	**1**	G	V
0003_00001_02.PNG	00001	0003	02	Verifying \G_8	8	**1**	**1**	G	V
0041_00029_00.PNG	00029	0041	00	Testing\N_068943	068943	**6**	**1**	N	T
0041_00029_01.PNG	00029	0041	01	Testing\G_0	0	**1**	**1**	G	T
0041_00029_02.PNG	00029	0041	02	Testing\G_6	6	**1**	**1**	G	T
0024_00076_00.PNG	00076	0024	00	Training\N_861	861	3	1	N	R
0024_00076_01.PNG	00076	0024	01	Training\G_8	8	1	1	G	R
0024_00076_02.PNG	00076	0024	02	Training\G_6	6	1	1	G	R
0024_00076_03.PNG	00076	0024	03	Training\G_1	1	1	1	G	R

D.3 Useful queries

These are some SQL examples that shows how easily researchers can extract useful information about the images:

- Numbers with 2 digits:
  ```
  SELECT * FROM [ALL] WHERE [DATABASE]="G" AND NCHARS=2
  ```

- Numbers written by a specified writer:
  ```
  SELECT * FROM [ALL] WHERE [DATABASE]="G" AND
  [SCAN]="00076"
  ```

- All the digits in the Training Set:
  ```
  SELECT * FROM [ALL] WHERE [DATABASE]="G" AND [SET]="R"
  ```

- Farsi letters in the Testing Set:
  ```
  SELECT * FROM [ALL] WHERE [DATABASE]="C" AND [SET]="T"
  ```

- Verifying Set for the letter "ب":
  ```
  SELECT * FROM [ALL] WHERE [SET] = "V" AND [LABEL]="ب"
  ```

Appendix E Samples of the Database

E.1 Samples of the fields in Form 1

Label	Sample	Label	Sample
Date	۱۳۵۹/۲/۲۸	0123456789	۰ ۱ ۲ ۳ ۴ ۵ ۶ ۷ ۸ ۹
9876543210	۹ ۸ ۷ ۶ ۵ ۴ ۳ ۲ ۱	82.7	۸۲/۷
5.94	۵/۹۴	0123456789 *(English)*	0 1 2 3 4 5 6 7 8 9
4953710628 *(English)*	4 9 5 3 7 1 0 62	60	۶۰
12	۱۲	29	۲۹
45	۴۵	37	۳۷
71	۷۱	14	۱۴
83	۸۳	58	۵۸
90	۹۰	86	۸۶
44	۴۴	28	۲۸
625	۶۲۵	853	۸۵۳
0100	۰۱۰۰	861	۸۶۱
940	۹۴۰	3012	۳۰۱۲
802	۸۰۲	745	۷۴۵
7135	۷۱۳۵	6203	۶۲۰۳
1839	۱۸۳۹	5586	۵۵۸۶
9007	۹۰۰۷	4.432	۴/۴۳۲
71000	۷۱۰۰۰	328000	۳۲۸۰۰۰
4600520	۴۶۰۰۵۲۰	758196	۷۵۸۱۹۶
127963	۱۲۷۹۶۳	1000000	۱۰۰۰۰۰۰
068943	۰۶۸۹۴۳	493794	۴۹۳۷۹۴

Label	Sample	Label	Sample
650971	۶۵۰۹۷۱	365497	۳۶۵۴۹۷
812763	۸۱۲۷۶۳		

Label	Sample
ب ژ س ط ع ج ف د ض م ک آ خ ر ش هـ ب	ب ژ س ط ع ج ف د ض م گ آ خ ر ش ه ب
ا ی ظ و ن ح ه ش ث غ ک هـ ل ج ذ ص ت ز	ا ی ظ و ن ح ه ش ث غ ک ه ل ج ذ ص ت ز
پ ش ظ ف ه ل ی ا ث ض ح ذ ن ت ر ک خ	پ ش ظ ف ه ل ی ا ث ض ح ذ ن ت ر ک خ
آ ب گ ز ص چ م ژ د ع ق س و ط خ ر ج غ	آ ه ب گ ز ص چ م ژ د ع ق س و ط خ ر ج غ

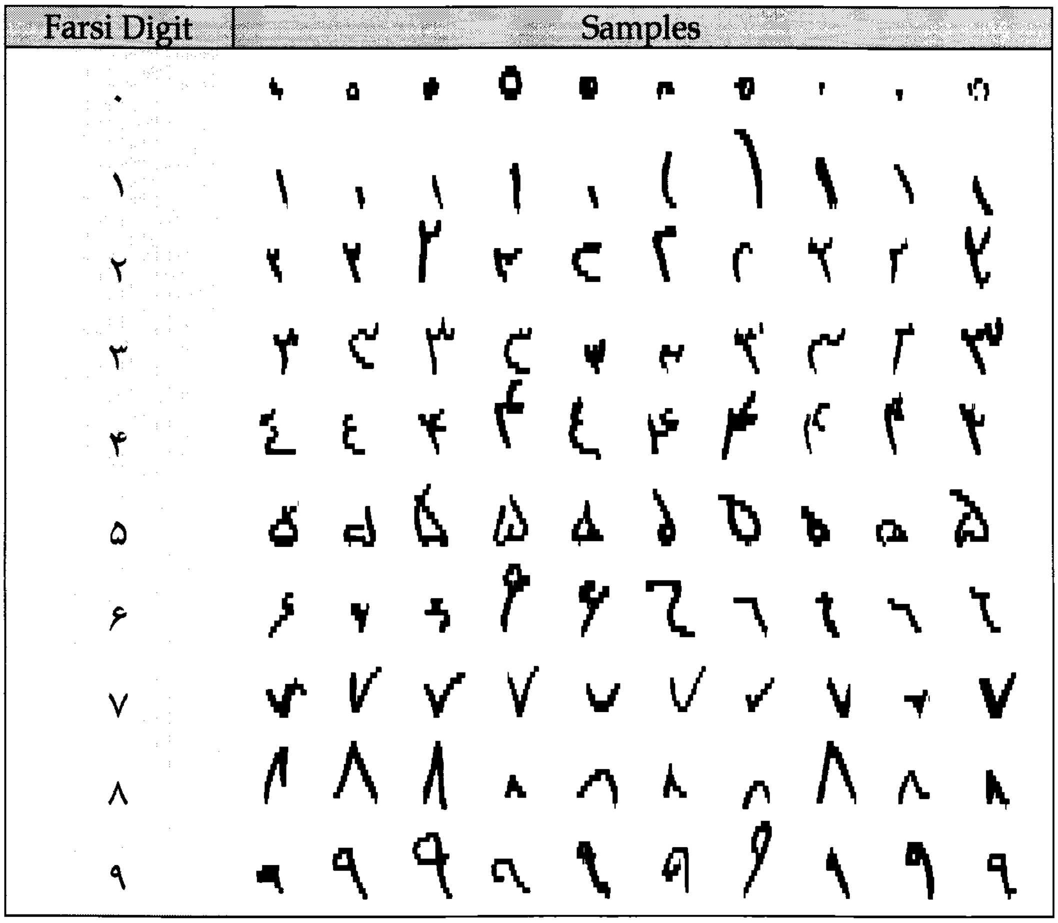
E.2 Samples of fields in Form 2

Field No.	Label	Sample
0050	یک	یک
0051	دو	دو
0052	سه	سه
0053	چهار	چهار
0054	پنج	پنج
0055	شش	شش
0056	هفت	هفت
0057	هشت	هشت
0058	نه	نه
0059	ده	ده
0060	یازده	یازده
0061	دوازده	دوازده
0062	سیزده	سیزده
0063	چهارده	چهارده
0064	پانزده	پانزده

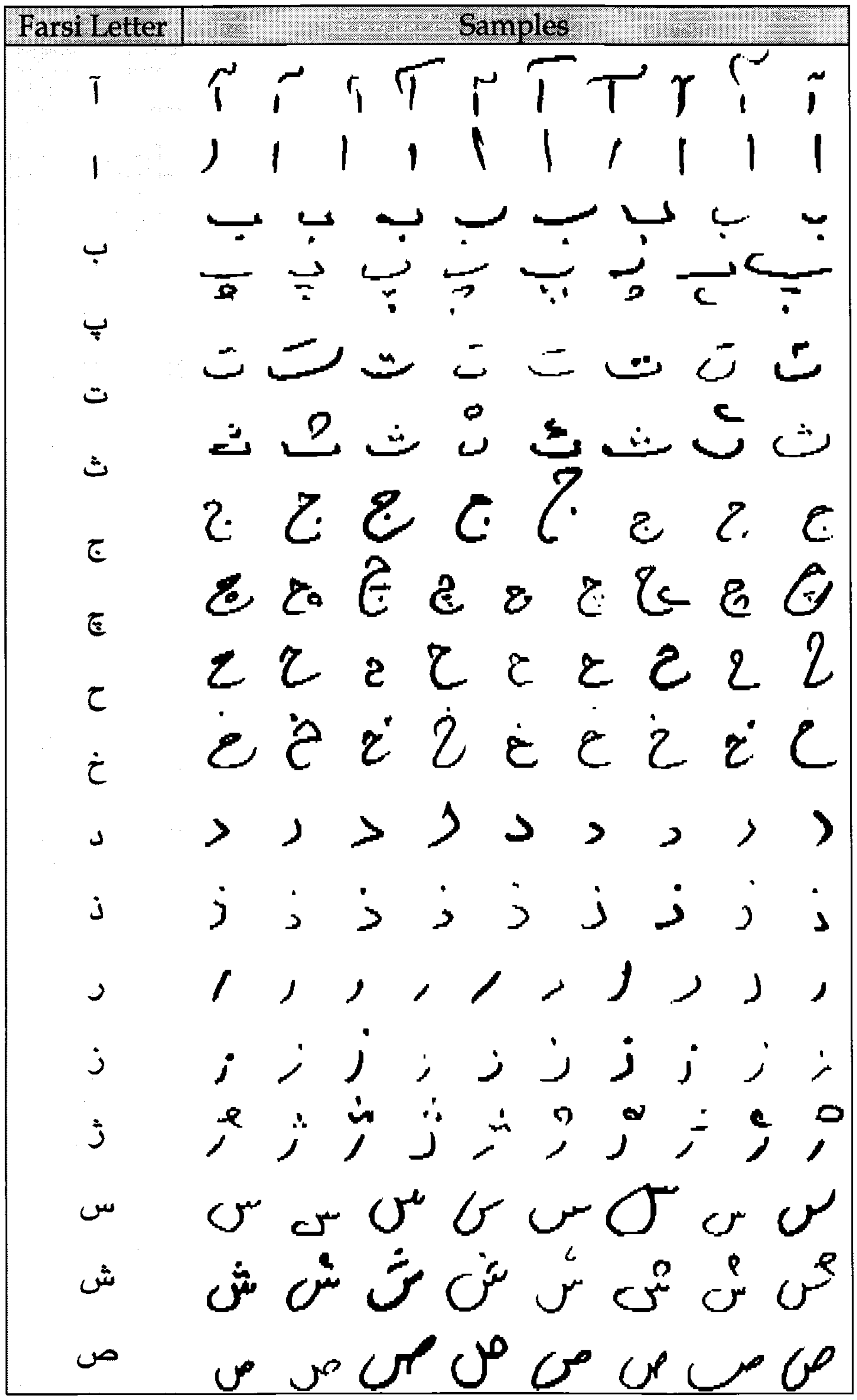
Field No.	Label	Sample
0065	شانزده	شانزده
0066	هفده	هفده
0067	هجده	هجده
0068	نوزده	نوزده
0069	بيست	بيست
0070	سى	سى
0071	چهل	چهل
0072	پنجاه	پنجاه
0073	شصت	شصت
0074	هفتاد	هفتاد
0075	هشتاد	هشتاد
0076	نود	نود
0077	صد	صد
0078	يكصد	يكصد
0079	دويست	دويست
0080	سيصد	سيصد
0081	چهارصد	چهارصد
0082	پانصد	پانصد
0083	ششصد	ششصد
0084	هفتصد	هفتصد
0085	هشتصد	هشتصد
0086	نهصد	نهصد
0087	هزار	هزار
0088	يكهزار	يكهزار

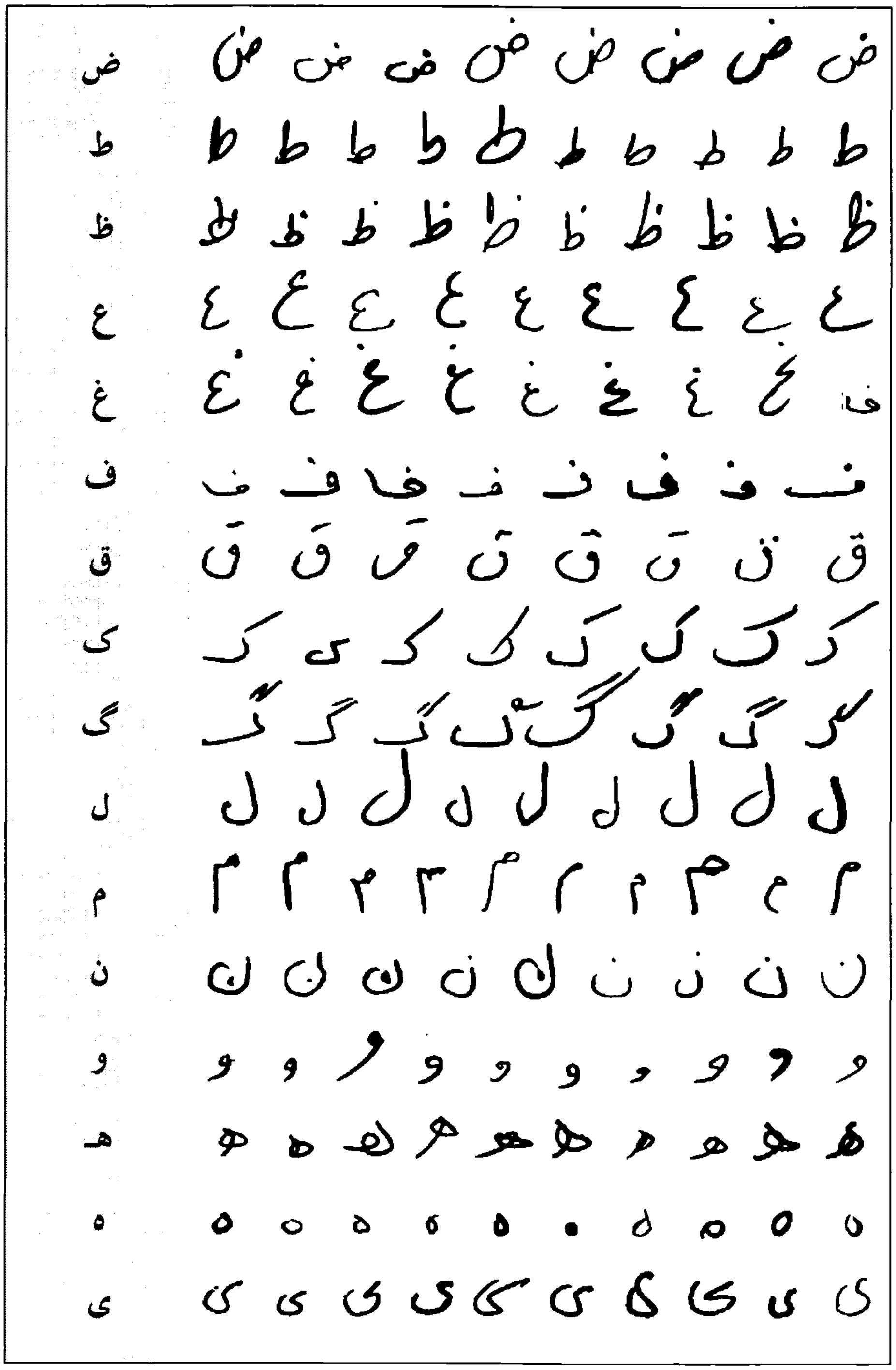
Field No.	Label	Sample
0089	میلیون	میلین
0090	میلیارد	میلیارد
0091	ریال	ریال
0092	تومان	تومان
0093	تمام	تمام
0094	معادل	معادل

E.3 Samples of isolated Farsi digits

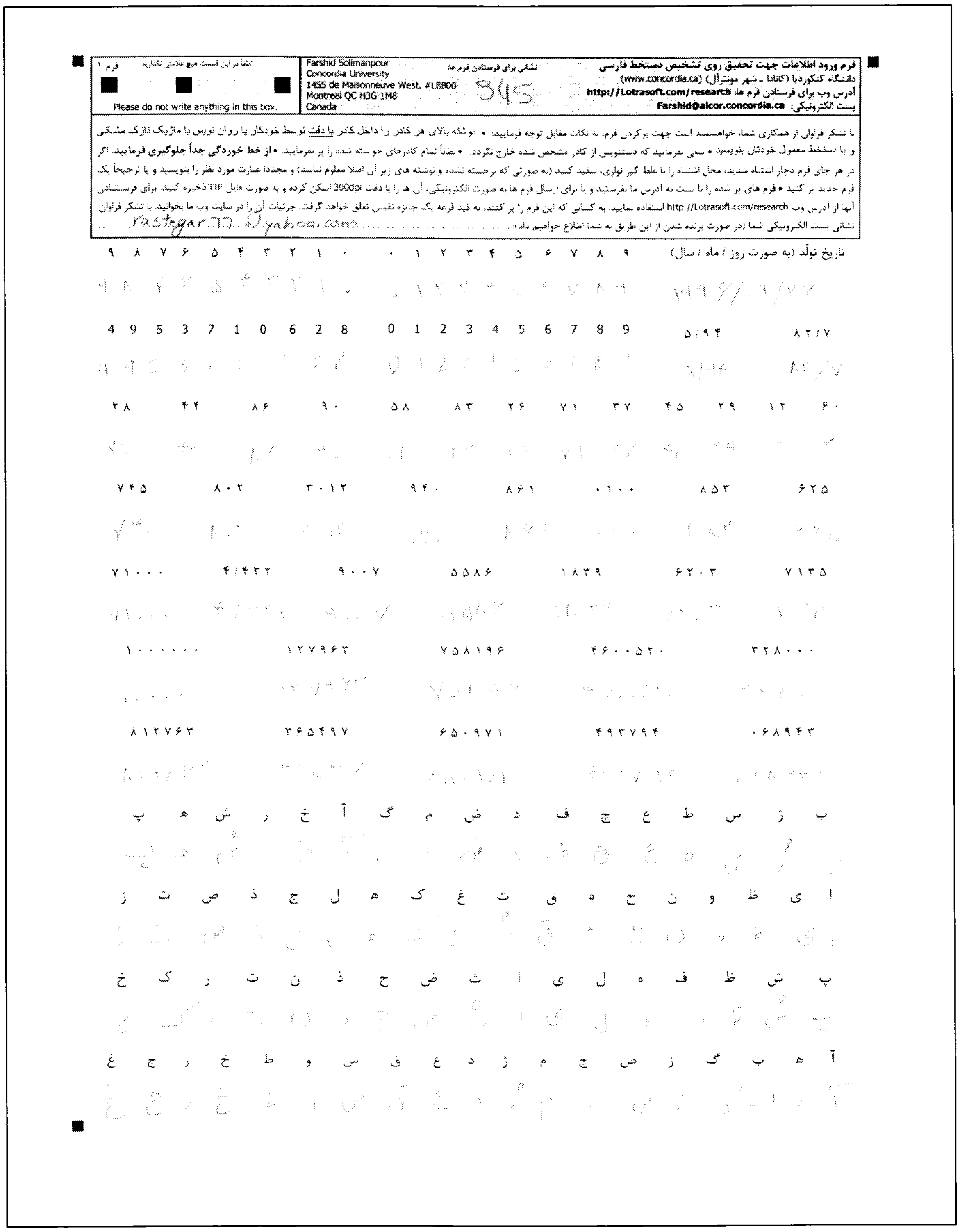


E.4 Samples of isolated Farsi letters




ض
ط
ظ
ع
غ
ف
ق
ک
گ
ل
م
ن
و
هـ
ه
ی

E.5 Samples of full forms



فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترآل) (www.concordia.ca)
آدرس وب برای فرستادن فرم ها: http://Lotrasoft.com/research
پست الکترونیکی: Farshid@alcor.concordia.ca

نشانی برای فرستادن فرم ها:
Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada

لطفاً در این قسمت هیچ علامتی نگذارید — فرم ۱
Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید: • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • **از خط خوردگی جداً جلوگیری فرمایید.** اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلا معلوم نباشند) و مجددا عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را با پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان.
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد): rastegar73@yahoo.com

تاریخ تولد (به صورت روز / ماه / سال)

۹ ۸ ۷ ۶ ۵ ۴ ۳ ۲ ۱ ۰   ۰ ۱ ۲ ۳ ۴ ۵ ۶ ۷ ۸ ۹

4 9 5 3 7 1 0 6 2 8   0 1 2 3 4 5 6 7 8 9   ۵/۹۴   ۸۲/۷

۲۸ ۴۴ ۸۶ ۹۰ ۵۸ ۸۳ ۲۶ ۷۱ ۳۷ ۴۵ ۲۹ ۱۲ ۶۰

۷۴۵ ۸۰۲ ۳۰۱۲ ۹۴۰ ۸۶۱ ۰۱۰۰ ۸۵۳ ۶۲۵

۷۱۰۰۰ ۴/۴۲۲ ۹۰۰۷ ۵۵۸۶ ۱۸۳۹ ۶۲۰۳ ۷۱۳۵

۱۰۰۰۰۰۰ ۱۲۷۹۶۳ ۷۵۸۱۹۶ ۴۶۰۰۵۲۰ ۳۲۸۰۰۰

۸۱۲۷۶۳ ۳۶۵۴۹۷ ۶۵۰۹۷۱ ۴۹۳۷۹۴ ۰۶۸۹۴۳

ب ژ س ط ع چ ف د ض م گ آ خ ر ش ه پ

ا ی ظ و ن ح ه ق ث غ ک ه ل چ ذ ص ت ژ

پ ش ظ ف ه ل ی ا ث ض ح ذ ن ت ر ک خ

آ ه ب گ ژ ص ج م ژ د غ ق س و ط خ ر چ غ

فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی دانشگاه کنکوردیا (کانادا ـ شهر مونترآل) (www.concordia.ca) آدرس وب برای فرستادن فرم ها: **http://Lotrasoft.com/research** پست الکترونیکی: **Farshid@alcor.concordia.ca**	نشانی برای فرستادن فرم ها: Farshid Solimanpour Concordia University 1455 de Maisonneuve West, #LB800 Montreal QC H3G 1M8 Canada 346	فرم ۲ لطفاً در این قسمت هیچ علامتی نگذارید. Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید: • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • **از خط خوردگی جداً جلوگیری فرمایید.** اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلاً معلوم نباشد) و مجدداً عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را با پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد): ....

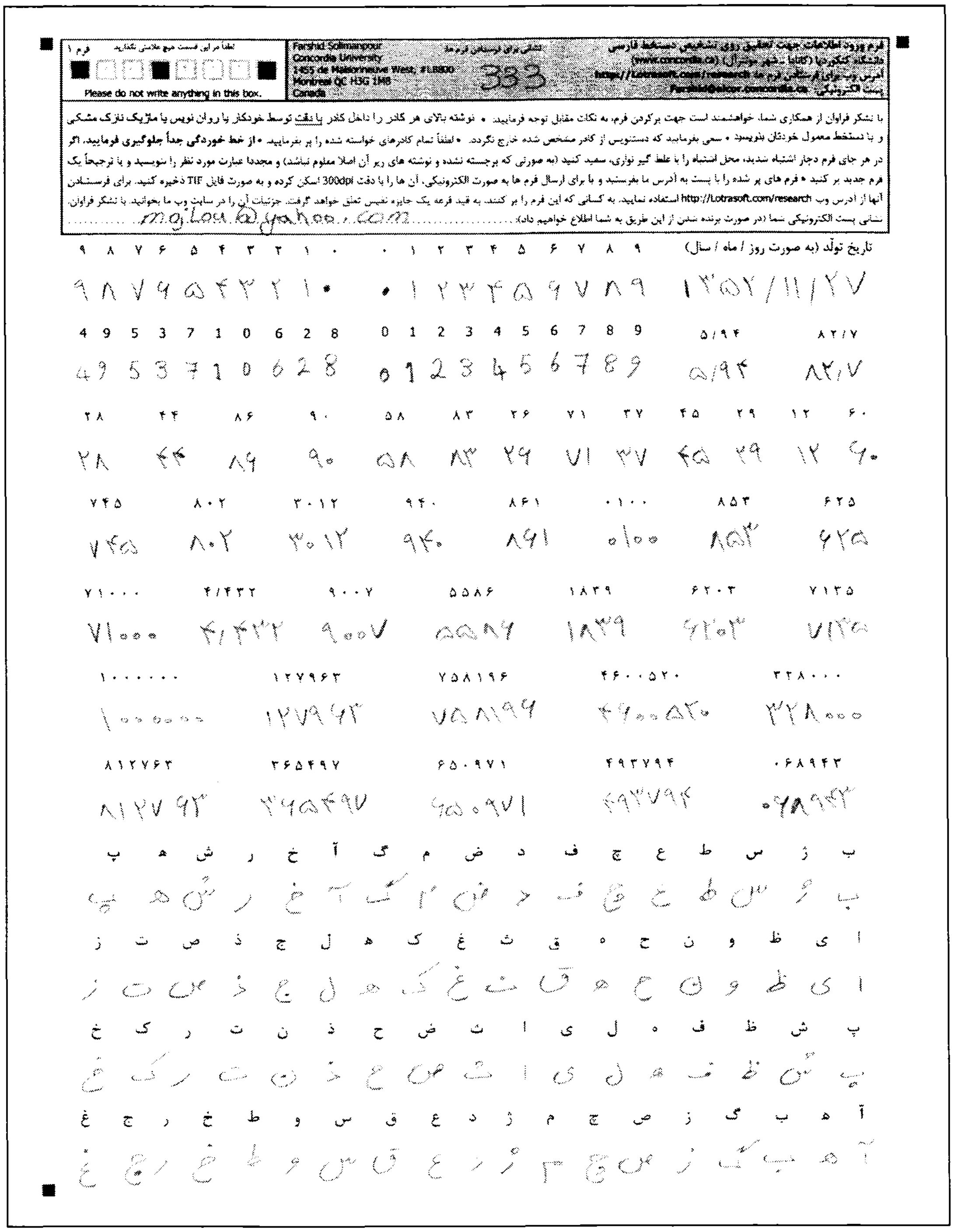
یک	دو	سه	چهار	پنج
شش	هفت	هشت	نه	ده
یازده	دوازده	سیزده	چهارده	پانزده
شانزده	هفده	هجده	نوزده	بیست
سی	چهل	پنجاه	شصت	هفتاد
هشتاد	نود	صد	یکصد	دویست
سیصد	چهارصد	پانصد	ششصد	هفتصد
هشتصد	نهصد	هزار	یکهزار	میلیون
میلیارد	ریال	تومان	تمام	معادل

سیصد و شصت هزار ریال

پانصد و سی و سه میلیون و هفتصد و شش

یکصد و چهل تومان تمام

[یک عدد به دلخواه خود به فارسی بنویسید]


فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترال) (www.concordia.ca)
Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada
383
Please do not write anything in this box.
فرم ۱
تاریخ تولّد (به صورت روز / ماه / سال)
۹ ۸ ۷ ۶ ۵ ۴ ۳ ۲ ۱ ۰
۰ ۱ ۲ ۳ ۴ ۵ ۶ ۷ ۸ ۹
4 9 5 3 7 1 0 6 2 8
0 1 2 3 4 5 6 7 8 9
۵/۹۴ ۸۲/۷
۲۸ ۴۴ ۸۶ ۹۰ ۵۸ ۸۳ ۲۶ ۷۱ ۳۷ ۴۵ ۲۹ ۱۲ ۶۰
۷۴۵ ۸۰۲ ۳۰۱۲ ۹۴۰ ۸۶۱ ۰۱۰۰ ۸۵۳ ۶۲۵
۷۱۰۰۰ ۴/۴۳۲ ۹۰۰۷ ۵۵۸۶ ۱۸۳۹ ۶۲۰۳ ۷۱۳۵
۱۰۰۰۰۰۰ ۱۲۷۹۶۳ ۷۵۸۱۹۶ ۴۶۰۰۵۲۰ ۳۲۸۰۰۰
۸۱۲۷۶۳ ۳۶۵۴۹۷ ۶۵۰۹۷۱ ۴۹۳۷۹۴ ۰۶۸۹۴۳
ب ز س ط ع چ ف د ض م گ آ خ ر ش ه پ
ا ی ظ و ن ح ه ق ث غ ک ه ل چ ذ ص ت ز
پ ش ظ ف ه ل ی ا ث ض ح ذ ن ت ر ک خ
آ ه ب گ ز ص چ م ژ د ع ق س و ط خ ر ج غ

فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی دانشگاه کنکوردیا (کانادا ـ شهر مونترآل) (www.concordia.ca) آدرس وب برای فرستادن فرم ها: http://Lotrasoft.com/research پست الکترونیکی: Farshid@alcor.concordia.ca	نشانی برای فرستادن فرم ها: Farshid Solimanpour Concordia University 1455 de Maisonneuve West, #LB800 Montreal QC H3G 1M8 Canada 334	لطفاً در این قسمت هیچ علامتی نگذارید. فرم ۲ Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید: • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • **از خط خوردگی جداً جلوگیری فرمایید.** اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلا معلوم نباشد) و مجددا عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را یا پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان.

نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد):..............................

یک	دو	سه	چهار	پنج
شش	هفت	هشت	نه	ده
یازده	دوازده	سیزده	چهارده	پانزده
شانزده	هفده	هجده	نوزده	بیست
سی	چهل	پنجاه	شصت	هفتاد
هشتاد	نود	صد	یکصد	دویست
سیصد	چهارصد	پانصد	ششصد	هفتصد
هشتصد	نهصد	هزار	یکهزار	میلیون
میلیارد	ریال	تومان	تمام	معادل

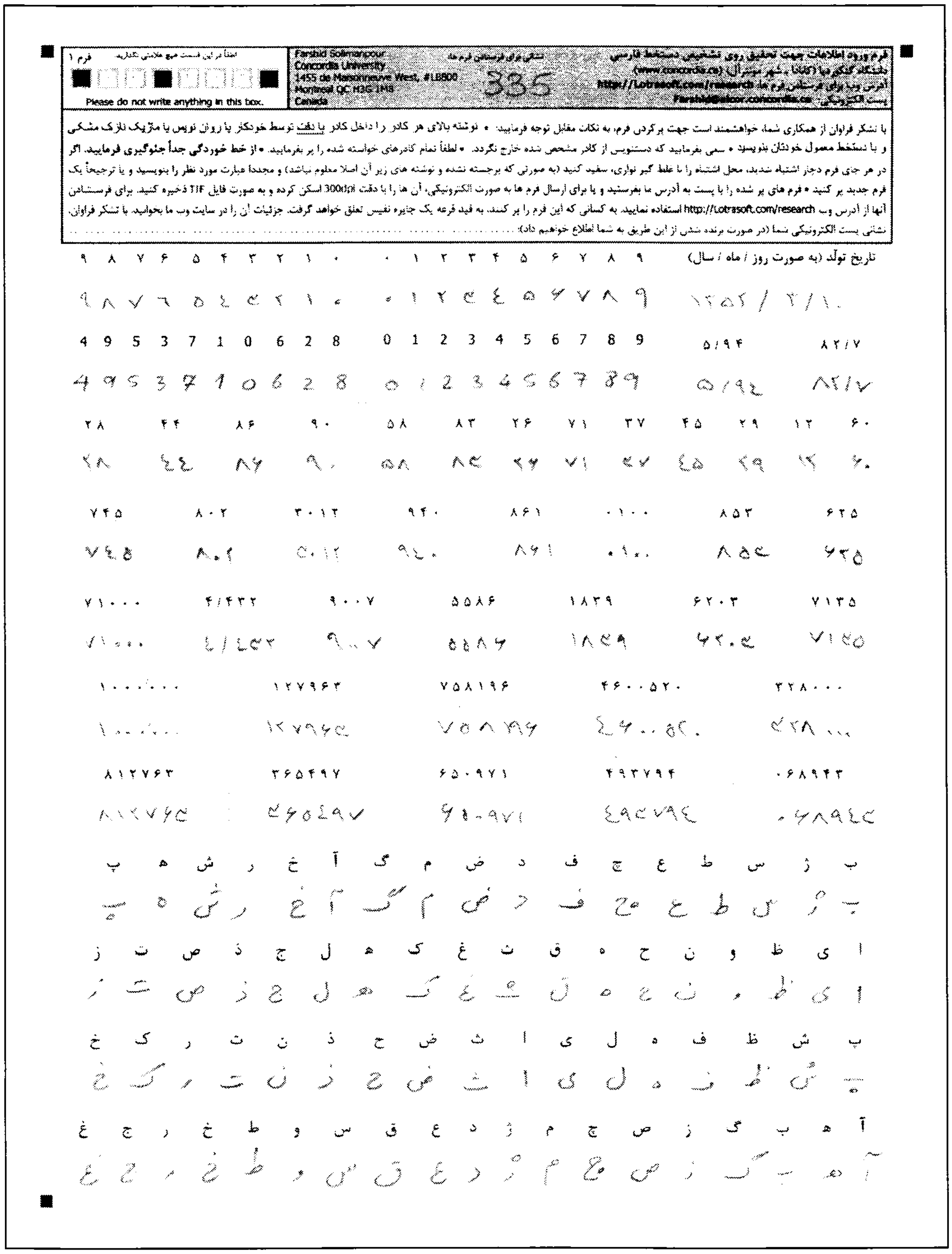
سیصد و شصت هزار ریال

پانصد و سی و سه میلیون و هفتصد و شش

یکصد و چهل تومان تمام

[یک عدد به دلخواه خود به فارسی بنویسید]

هفت هزار و نوزده



فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترال) (www.concordia.ca)
آدرس وب برای فرستادن فرم ها: http://Lotrasoft.com/research
پست الکترونیکی: Farshid@alcor.concordia.ca

نشانی برای فرستادن فرم ها:
Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada

لطفاً در این قسمت هیچ علامتی نگذارید. فرم ۱
Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پر کردن فرم، به نکات مقابل توجه فرمایید: • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • از خط خوردگی جداً جلوگیری فرمایید. اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلاً معلوم نباشد) و مجدداً عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را با پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان.
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد):..........

تاریخ تولد (به صورت روز / ماه / سال) ۹ ۸ ۷ ۶ ۵ ۴ ۳ ۲ ۱ ۰ ۰ ۱ ۲ ۳ ۴ ۵ ۶ ۷ ۸ ۹

۸۲/۷ ۵/۹۴ 0 1 2 3 4 5 6 7 8 9 4 9 5 3 7 1 0 6 2 8

۶۰ ۱۲ ۲۹ ۴۵ ۳۷ ۷۱ ۲۶ ۸۳ ۵۸ ۹۰ ۸۶ ۴۴ ۲۸

۶۲۵ ۸۵۳ ۰۱۰۰ ۸۶۱ ۹۴۰ ۳۰۱۲ ۸۰۲ ۷۴۵

۷۱۳۵ ۶۲۰۳ ۱۸۳۹ ۵۵۸۶ ۹۰۰۷ ۴/۴۳۲ ۷۱۰۰۰

۳۲۸۰۰۰ ۴۶۰۰۵۲۰ ۷۵۸۱۹۶ ۱۲۷۹۶۳ ۱۰۰۰/۰۰۰

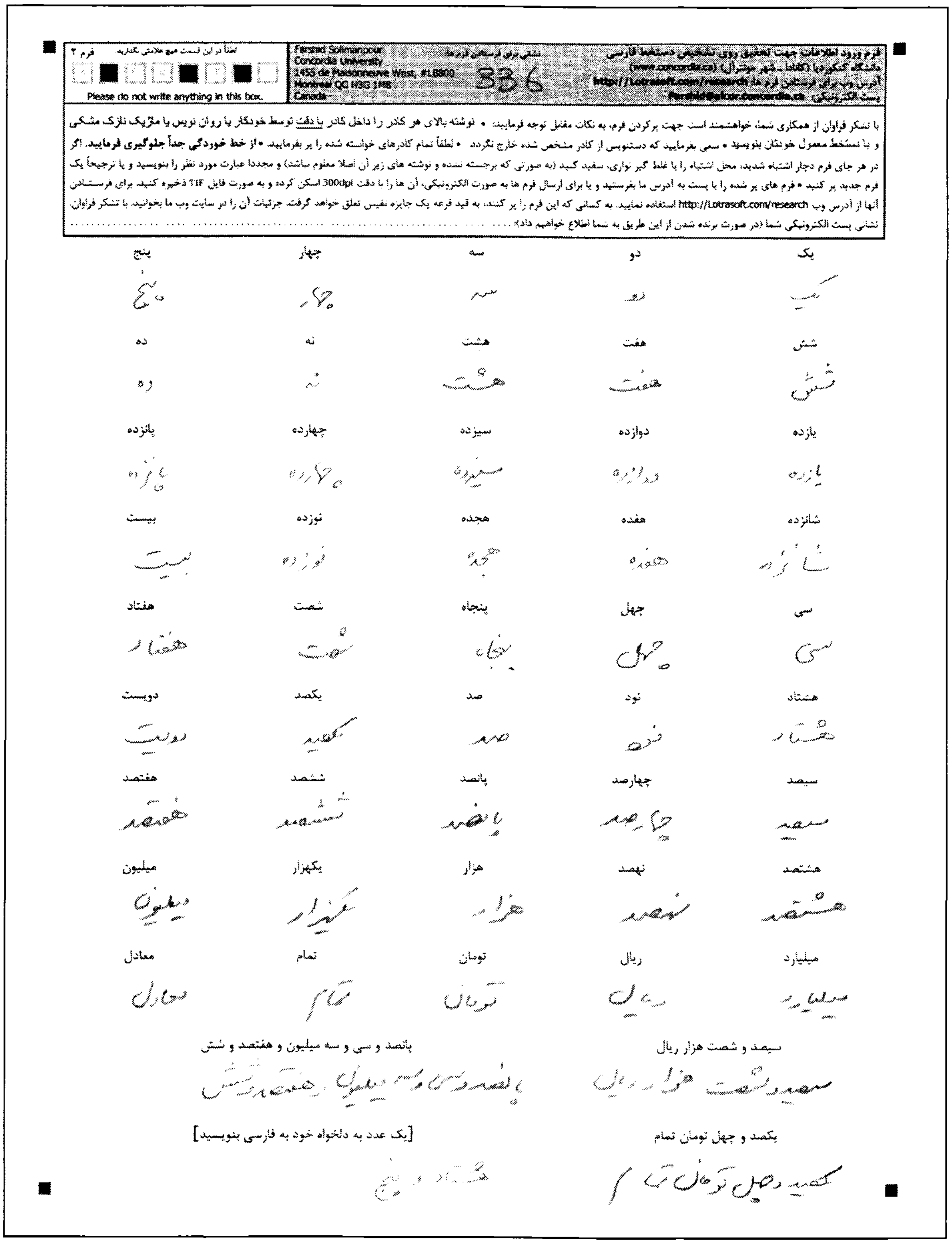
۰۶۸۹۴۳ ۴۹۳۷۹۴ ۶۵۰۹۷۱ ۳۶۵۴۹۷ ۸۱۲۷۶۳

ب ژ س ط ع چ ف د ض م گ آ خ ر ش ه پ

ا ی ظ و ن ح ه ق ث غ ک ه ل چ ذ ص ت ز

پ ش ظ ف ه ل ی ا ث ض ح ذ ن ث ر ک خ

آ ه ب گ ز ص چ م ژ د ع ق س و ط خ ر ج غ



فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترال) (www.concordia.ca)
آدرس وب برای فرستادن فرم ها: http://Lotrasoft.com/research
پست الکترونیکی: Farshid@alcor.concordia.ca

نشانی برای فرستادن فرم ها:
Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada

336

لطفاً در این قسمت هیچ علامتی نگذارید. فرم ۳
Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید: • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد • لطفاً تمام کادرهای خواسته شده را پر بفرمایید • **از خط خوردگی جداً جلوگیری فرمایید.** اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلاً معلوم نباشد) و مجدداً عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را با پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان.
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد): ....

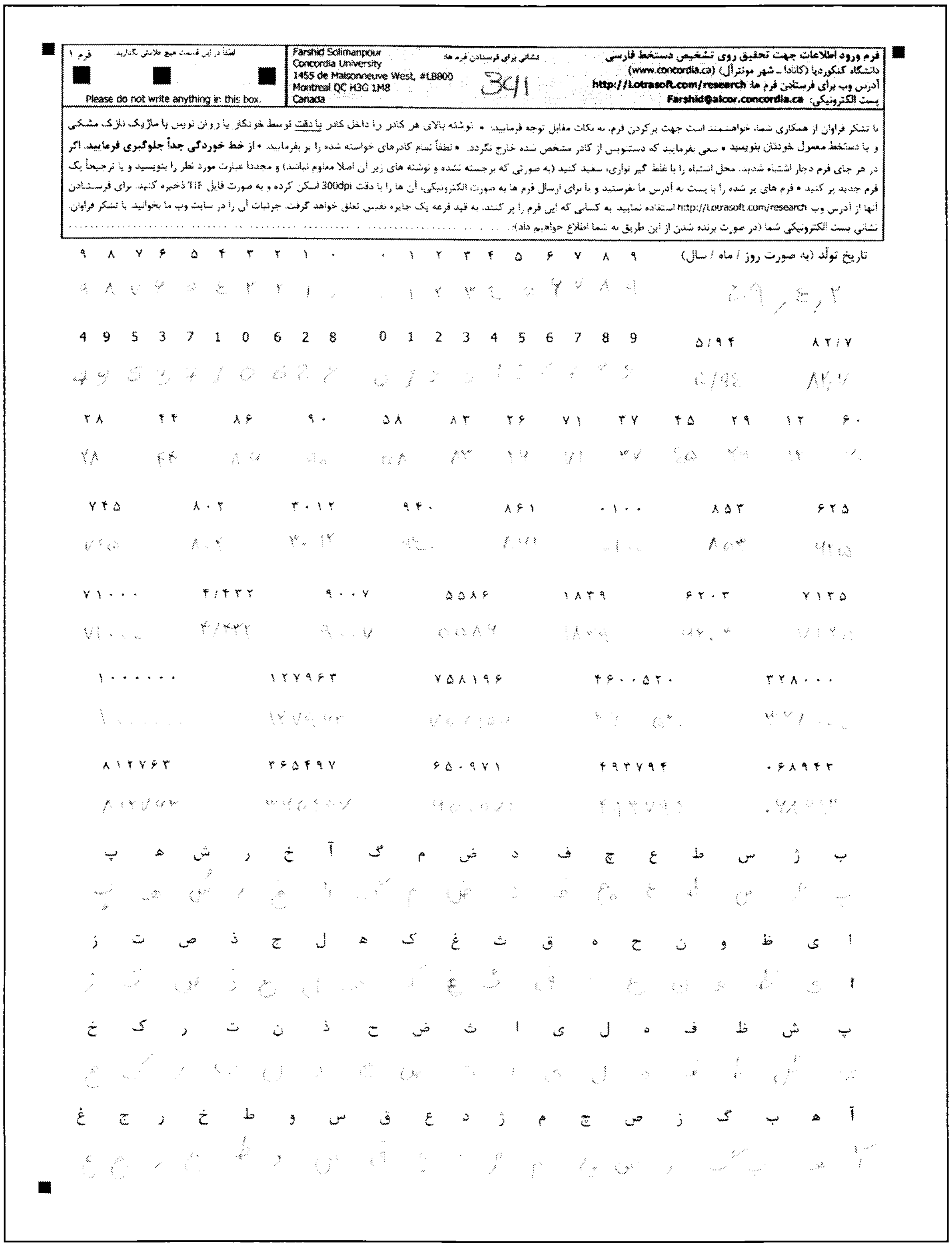
یک	دو	سه	چهار	پنج
شش	هفت	هشت	نه	ده
یازده	دوازده	سیزده	چهارده	پانزده
شانزده	هفده	هجده	نوزده	بیست
سی	چهل	پنجاه	شصت	هفتاد
هشتاد	نود	صد	یکصد	دویست
سیصد	چهارصد	پانصد	ششصد	هفتصد
هشتصد	نهصد	هزار	یکهزار	میلیون
میلیارد	ریال	تومان	تمام	معادل

سیصد و شصت هزار ریال

پانصد و سی و سه میلیون و هفتصد و شش

یکصد و چهل تومان تمام

[یک عدد به دلخواه خود به فارسی بنویسید]



فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترآل) (www.concordia.ca)
آدرس وب برای فرستادن فرم ها: http://Lotrasoft.com/research
پست الکترونیکی: Farshid@alcor.concordia.ca

نشانی برای فرستادن فرم ها:
Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada

341

لطفاً در این قسمت هیچ علامتی نگذارید. فرم ۱
Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید: • نوشته بالای هر کادر را داخل کادر با دقت توسط خودنکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • از خط خوردگی جداً جلوگیری فرمایید. اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلا معلوم نباشد) و مجدداً عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را با پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد): ....

۹ ۸ ۷ ۶ ۵ ۴ ۳ ۲ ۱ ۰ ۰ ۱ ۲ ۳ ۴ ۵ ۶ ۷ ۸ ۹ تاریخ تولد (به صورت روز / ماه / سال)

4 9 5 3 7 1 0 6 2 8 0 1 2 3 4 5 6 7 8 9 ۵/۹۴ ۸۲/۷

۲۸ ۴۴ ۸۶ ۹۰ ۵۸ ۸۳ ۲۶ ۷۱ ۳۷ ۴۵ ۲۹ ۱۲ ۶۰

۷۴۵ ۸۰۲ ۳۰۱۲ ۹۴۰ ۸۶۱ ۰۱۰۰ ۸۵۳ ۶۲۵

۷۱۰۰۰ ۴/۴۳۲ ۹۰۰۷ ۵۵۸۶ ۱۸۳۹ ۶۲۰۳ ۷۱۳۵

۱۰۰۰۰۰۰ ۱۲۷۹۶۳ ۷۵۸۱۹۶ ۴۶۰۰۵۲۰ ۳۲۸۰۰۰

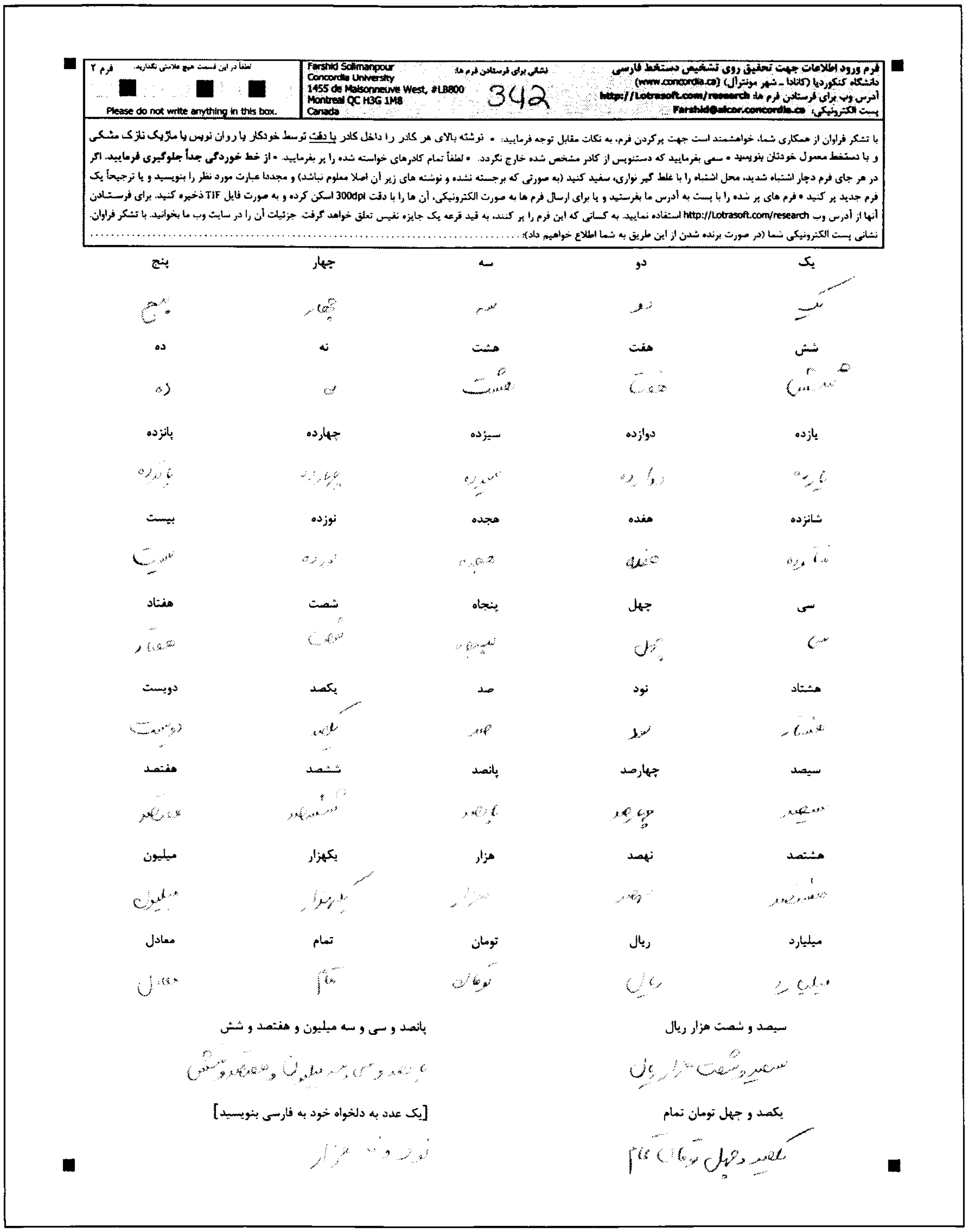
۸۱۲۷۶۳ ۳۶۵۴۹۷ ۶۵۰۹۷۱ ۴۹۳۷۹۴ ۰۶۸۹۴۳

ب ژ س ط ع چ ف د ض م گ آ خ ر ش ه پ

ا ی ظ و ن ح ه ق ث غ ک ه ل ج ذ ص ت ز

پ ش ظ ف ه ل ی ا ث ض ح ذ ن ت ر ک خ

آ ه ب گ ز ص چ م ژ د ع ق س و ط خ ر ج غ



فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترآل) (www.concordia.ca)
آدرس وب برای فرستادن فرم ها: http://Lotrasoft.com/research
پست الکترونیکی: Farshid@alcor.concordia.ca

نشانی برای فرستادن فرم ها:
Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada

342

لطفاً در این قسمت هیچ علامتی نگذارید. فرم ۲
Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید: • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • از خط خوردگی جداً جلوگیری فرمایید. اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلا معلوم نباشد) و مجددا عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را با پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان.
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد): ....

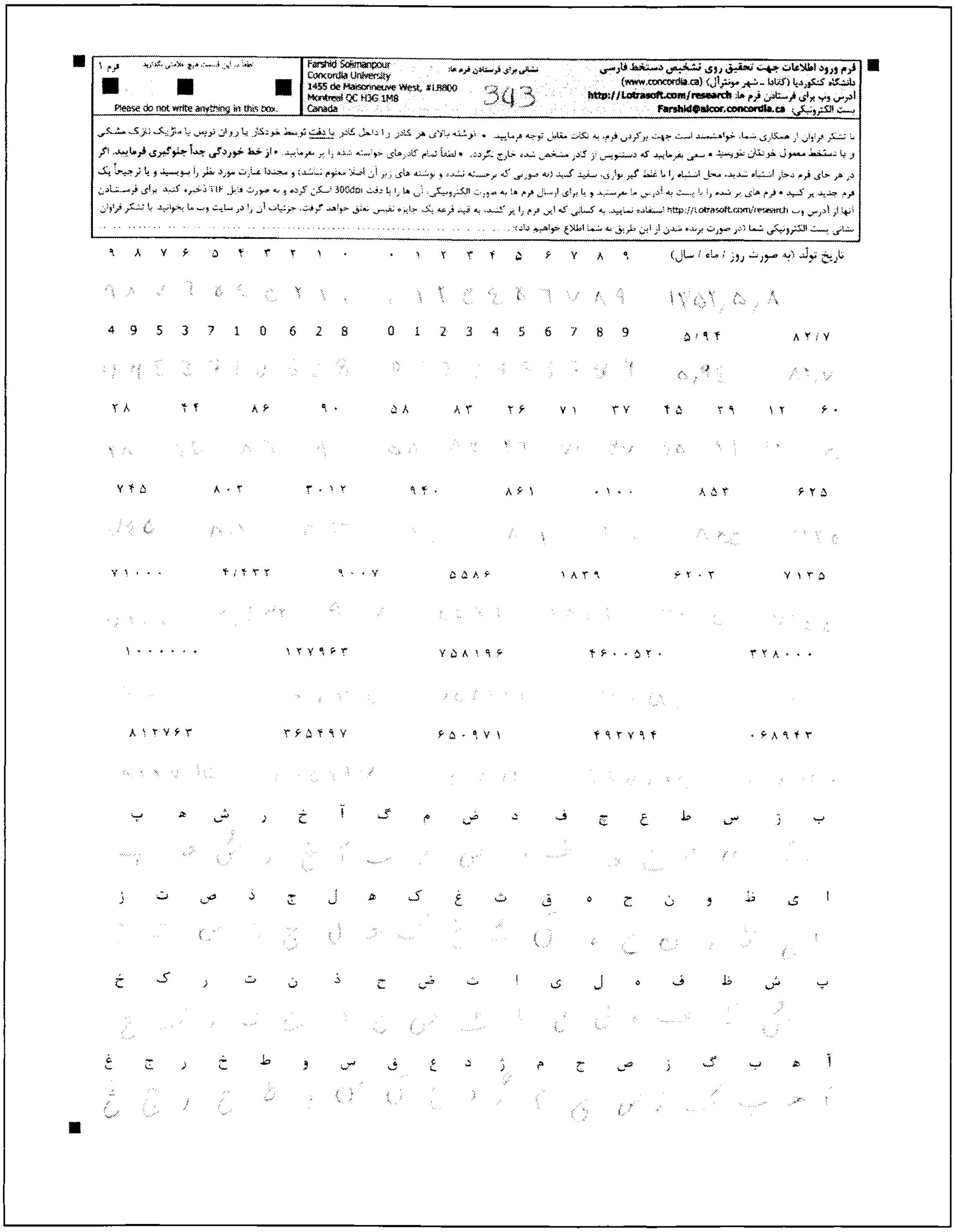
یک	دو	سه	چهار	پنج
شش	هفت	هشت	نه	ده
یازده	دوازده	سیزده	چهارده	پانزده
شانزده	هفده	هجده	نوزده	بیست
سی	چهل	پنجاه	شصت	هفتاد
هشتاد	نود	صد	یکصد	دویست
سیصد	چهارصد	پانصد	ششصد	هفتصد
هشتصد	نهصد	هزار	یکهزار	میلیون
میلیارد	ریال	تومان	تمام	معادل

سیصد و شصت هزار ریال

پانصد و سی و سه میلیون و هفتصد و شش

یکصد و چهل تومان تمام

[یک عدد به دلخواه خود به فارسی بنویسید]



فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترآل) (www.concordia.ca)
آدرس وب برای فرستادن فرم ها: **http://Lotrasoft.com/research**
پست الکترونیکی: **Farshid@alcor.concordia.ca**

نشانی برای فرستادن فرم ها:
Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada

343

لطفاً در این قسمت هیچ علامتی نگذارید   فرم ۱
Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید. • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • **از خط خوردگی جداً جلوگیری فرمایید.** اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلاً معلوم نباشد) و مجدداً عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را یا پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد): ....

تاریخ تولّد (به صورت روز / ماه / سال)   ۹ ۸ ۷ ۶ ۵ ۴ ۳ ۲ ۱ ۰   ۰ ۱ ۲ ۳ ۴ ۵ ۶ ۷ ۸ ۹

4 9 5 3 7 1 0 6 2 8   0 1 2 3 4 5 6 7 8 9   ۵/۹۴   ۸۲/۷

۲۸   ۴۴   ۸۶   ۹۰   ۵۸   ۸۳   ۲۶   ۷۱   ۳۷   ۴۵   ۲۹   ۱۲   ۶۰

۷۴۵   ۸۰۳   ۳۰۱۲   ۹۴۰   ۸۶۱   ۰۱۰۰   ۸۵۳   ۶۲۵

۷۱۰۰۰   ۴/۴۳۲   ۹۰۰۷   ۵۵۸۶   ۱۸۳۹   ۶۲۰۳   ۷۱۳۵

۱۰۰۰۰۰۰   ۱۲۷۹۶۳   ۷۵۸۱۹۶   ۴۶۰۰۵۲۰   ۳۲۸۰۰۰

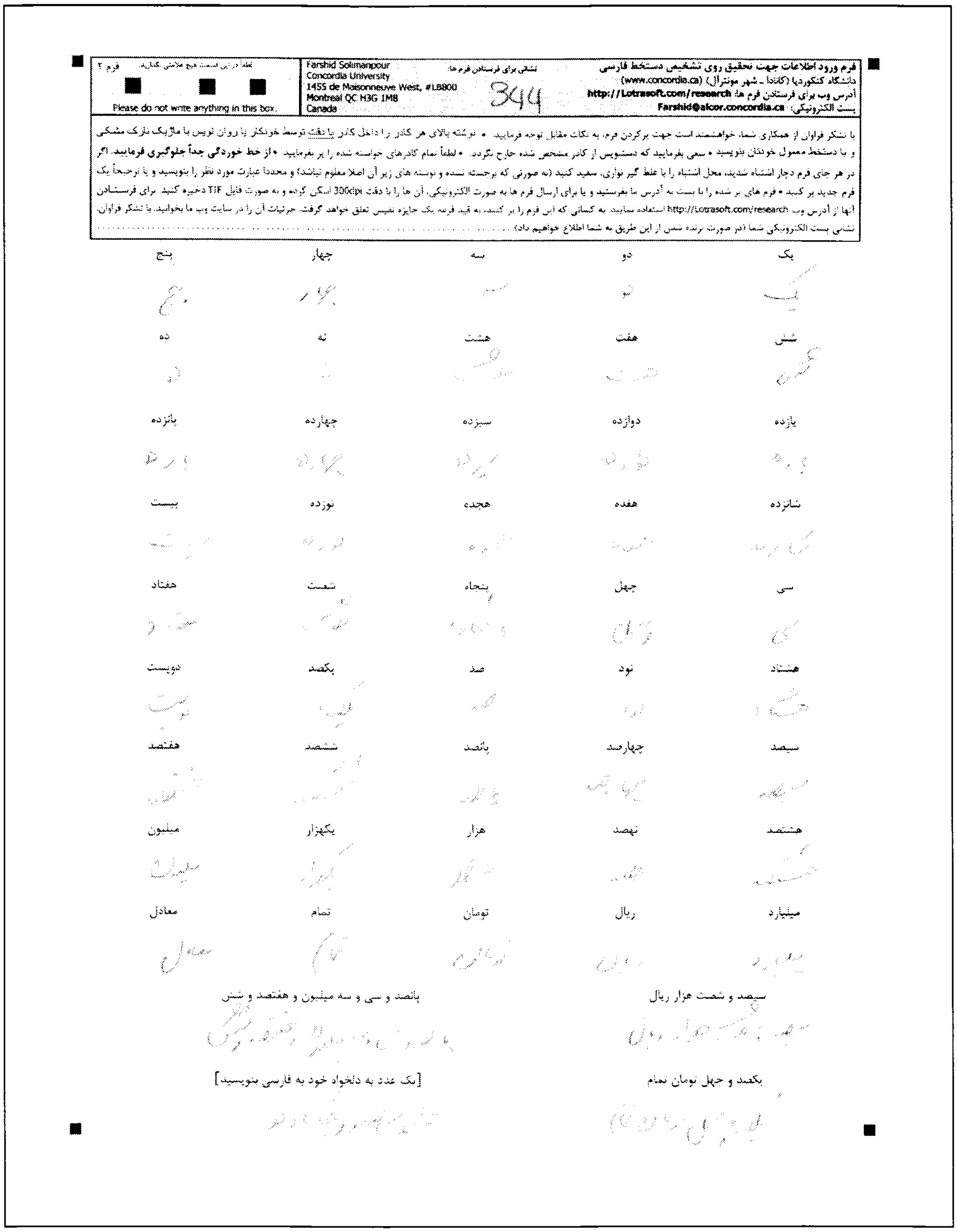
۸۱۲۷۶۳   ۳۶۵۴۹۷   ۶۵۰۹۷۱   ۴۹۲۷۹۴   ۰۶۸۹۴۳

ب ژ س ط ع چ ف د ض م گ آ خ ر ش ه پ

ا ی ظ و ن ح ه ق ث غ ک ه ل ج ذ ص ت ز

پ ش ظ ف ه ل ی ا ث ض ح ذ ن ت ر ک خ

آ ه ب گ ز ص ح م ژ د ع ق س و ط خ ر ج غ



فرم ورود اطلاعات جهت تحقیق روی تشخیص دستخط فارسی
دانشگاه کنکوردیا (کانادا ـ شهر مونترال) (www.concordia.ca)
آدرس وب برای فرستادن فرم ها: **http://Lotrasoft.com/research**
پست الکترونیکی: **Farshid@alcor.concordia.ca**

نشانی برای فرستادن فرم ها:
344

Farshid Solimanpour
Concordia University
1455 de Maisonneuve West, #LB800
Montreal QC H3G 1M8
Canada

لطفاً در این قسمت هیچ علامتی نگذارید. فرم ۲
Please do not write anything in this box.

با تشکر فراوان از همکاری شما، خواهشمند است جهت پرکردن فرم، به نکات مقابل توجه فرمایید. • نوشته بالای هر کادر را داخل کادر با دقت توسط خودکار یا روان نویس یا ماژیک نازک مشکی و با دستخط معمول خودتان بنویسید • سعی بفرمایید که دستنویس از کادر مشخص شده خارج نگردد. • لطفاً تمام کادرهای خواسته شده را پر بفرمایید. • **از خط خوردگی جداً جلوگیری فرمایید.** اگر در هر جای فرم دچار اشتباه شدید، محل اشتباه را با غلط گیر نواری، سفید کنید (به صورتی که برجسته نشده و نوشته های زیر آن اصلا معلوم نباشد) و مجدداً عبارت مورد نظر را بنویسید و یا ترجیحاً یک فرم جدید پر کنید • فرم های پر شده را با پست به آدرس ما بفرستید و یا برای ارسال فرم ها به صورت الکترونیکی، آن ها را با دقت 300dpi اسکن کرده و به صورت فایل TIF ذخیره کنید. برای فرستادن آنها از آدرس وب http://Lotrasoft.com/research استفاده نمایید. به کسانی که این فرم را پر کنند، به قید قرعه یک جایزه نفیس تعلق خواهد گرفت. جزئیات آن را در سایت وب ما بخوانید. با تشکر فراوان.
نشانی پست الکترونیکی شما (در صورت برنده شدن از این طریق به شما اطلاع خواهیم داد). ....

یک	دو	سه	چهار	پنج
شش	هفت	هشت	نه	ده
یازده	دوازده	سیزده	چهارده	پانزده
شانزده	هفده	هجده	نوزده	بیست
سی	چهل	پنجاه	شصت	هفتاد
هشتاد	نود	صد	یکصد	دویست
سیصد	چهارصد	پانصد	ششصد	هفتصد
هشتصد	نهصد	هزار	یکهزار	میلیون
میلیارد	ریال	تومان	تمام	معادل

سیصد و شصت هزار ریال — پانصد و سی و سه میلیون و هفتصد و شش

یکصد و چهل تومان تمام — [یک عدد به دلخواه خود به فارسی بنویسید]

Appendix F An Introduction to Support Vector Machines

The support vector machine (SVM) is a training algorithm used for learning classification and regression rules from data and it is the classifier we used for our recognition system. SVMs were first suggested by Vapnik in the 1960s for classification, and have recently become an area of intense research owing to developments in the techniques and theory coupled with extensions to regression and density estimation. In the following sections we briefly describe how SVM works, but detailed information can be retrieved from [22][22].

5.1 Principle of SVM

In pattern recognition, SVM tries constructing a hyperplane (generalization of a plane in a three-dimensional space, to more than three dimensions) as a target which separates the positive and negative patterns with the largest possible margin. Figure 32 illustrates this in a two-dimensional environment and with two classes.

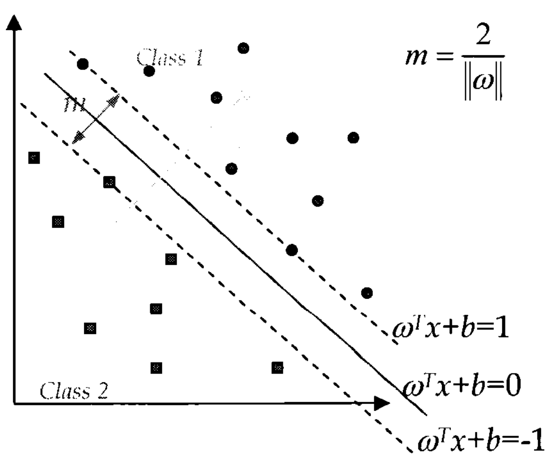


Figure 32 Illustration of large margin decision boundary in SVM

5.2 SVM generalization

Given a Training Set of instance-label pairs $(x_i, y_i), i = 1,...,l$ where $x_i \in R^n$ and $y_i \in \{1,-1\}^l$, the SVMs require the solution for the following optimization problem:

$$\min_{\omega,b,\xi} \frac{1}{2}\omega^T \omega + C\sum_{i=1}^{l}\xi_i$$
$$\text{Subject to } y_i\left(\omega^T \phi(x_i) + b\right) \geq 1 - \xi_i, \xi_i \geq 0. \quad (1)$$

Here, training vectors x_i are mapped into a higher (usually infinite) dimensional space by the function ϕ. Then, SVM finds a linear separating hyperplane with the maximal margin in this higher dimensional space. ξ is the error, and C > 0 is the penalty parameter of the error term. Figure 33 shows how the mapping function ϕ works.

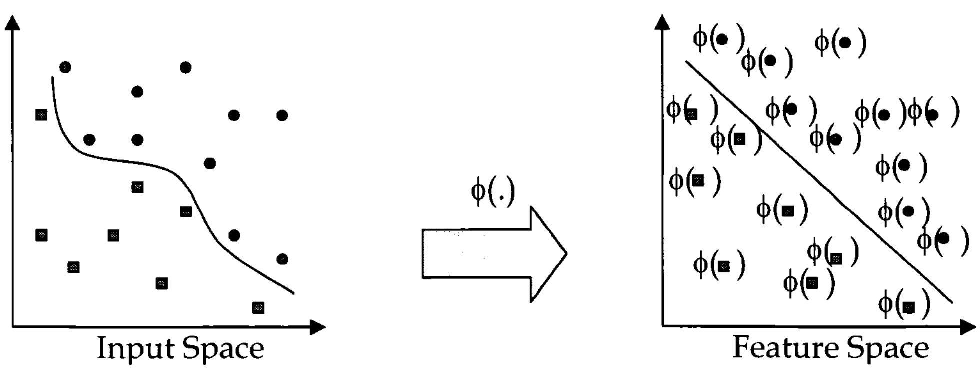


Figure 33 Illustration of the mapping function ϕ in the SVM optimization problem

5.3 The kernel function

As discussed, the mapping function ϕ maps the input space into an infinite dimension feature space, which is difficult to calculate and costly (because it is high-dimensional). By defining a new function as $K(x_i, x_j) \equiv \phi(x_i)^T \phi(x_j)$, which is called the kernel function we will not have to carry out $\phi(.)$ explicitly any more. These four basic kernels are used by researchers:

- Linear: $K(x_i, x_j) \equiv x_i^T x_j$.
- Polynomial: $K(x_i, x_j) = (\gamma x_i^T x_j + r)^d, \gamma > 0$.
- Radial Basis Function (RBF): $K(x_i, x_j) \equiv \exp(-\gamma \|x_i - x_j\|^2), \gamma > 0$.
- Sigmoid: $K(x_i, x_j) \equiv \tanh(\gamma x_i^T x_j + r)$.

Where γ, r and d are kernel parameters.

5.4 Multi-Class Classification with SVM

SVM is basically a two-class classifier. Researchers have tried different ways of adopting the SVM classifier for classifying multiple classes. The most common way is by dividing the dataset into two parts intelligently in different ways. A separate SVM is trained for each way of division. Multi-class classification is done by combining the output of all the SVM classifiers.

Appendix G Deciding rejection threshold

For deciding the rejection threshold for each class, the threshold is set from 0 to 0.9 with steps of 0.02, and at each step, the rejection and error rates are recorded in a table shown as Table 17. Then from this table the threshold that gives the best result is selected for each class. To find the best result we searched for the values that keep the error rate less than 1% unless the rejection rate goes higher than 5%.

Table 17 Rejection and error rates for different rejection thresholds

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
0	0.10	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.12	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.14	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.16	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.18	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.20	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.22	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.24	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.26	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.28	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.30	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.32	4.00%	0.00%	2.36%	0.00%	2.20%	0.00%
0	0.34	3.50%	0.50%	2.36%	0.00%	1.80%	0.40%
0	0.36	3.50%	0.50%	2.36%	0.00%	1.80%	0.40%
0	0.38	3.50%	0.50%	2.36%	0.00%	1.60%	0.60%
0	0.40	3.50%	0.50%	2.36%	0.00%	1.40%	0.80%
0	0.42	3.50%	0.50%	2.36%	0.00%	1.20%	1.00%
0	0.44	3.50%	0.50%	2.36%	0.00%	1.20%	1.00%
0	0.46	3.00%	1.00%	2.36%	0.00%	1.20%	1.00%
0	0.48	2.50%	1.50%	2.36%	0.00%	1.20%	1.00%
0	0.50	2.50%	1.50%	2.36%	0.00%	1.20%	1.00%
0	0.52	2.50%	19.50%	2.18%	24.36%	1.20%	24.00%
0	0.54	2.00%	21.50%	2.18%	27.91%	1.20%	26.00%
0	0.56	2.00%	22.00%	2.18%	29.09%	1.00%	26.20%
0	0.58	2.00%	22.00%	2.18%	31.64%	1.00%	26.60%
0	0.60	2.00%	22.50%	2.00%	32.09%	1.00%	27.20%
0	0.62	2.00%	22.50%	2.00%	32.55%	1.00%	27.40%
0	0.64	1.50%	23.00%	2.00%	32.64%	1.00%	27.40%
0	0.66	1.50%	23.50%	1.91%	32.91%	0.80%	28.00%
0	0.68	1.50%	23.50%	1.82%	33.18%	0.60%	29.20%
0	0.70	1.00%	24.00%	1.82%	33.55%	0.60%	29.20%
0	0.72	1.00%	24.00%	1.82%	33.55%	0.60%	29.40%
0	0.74	1.00%	24.00%	1.82%	33.82%	0.60%	29.40%
0	0.76	1.00%	24.00%	1.64%	34.18%	0.60%	29.40%
0	0.78	1.00%	24.00%	1.64%	34.18%	0.60%	29.80%
0	0.80	1.00%	24.00%	1.45%	34.55%	0.60%	29.80%

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
0	0.82	0.50%	25.00%	1.27%	35.00%	0.40%	30.00%
0	0.84	0.50%	25.00%	1.18%	35.18%	0.40%	30.20%
0	0.86	0.50%	25.50%	1.18%	35.27%	0.20%	30.80%
0	0.88	0.50%	25.50%	0.82%	35.64%	0.20%	30.80%
1	0.10	3.00%	0.00%	1.82%	0.00%	5.20%	0.00%
1	0.12	3.00%	0.00%	1.82%	0.00%	5.20%	0.00%
1	0.14	3.00%	0.00%	1.82%	0.00%	5.20%	0.00%
1	0.16	3.00%	0.00%	1.82%	0.00%	5.20%	0.00%
1	0.18	3.00%	0.00%	1.82%	0.00%	5.20%	0.00%
1	0.20	3.00%	0.00%	1.82%	0.00%	5.20%	0.00%
1	0.22	3.00%	0.00%	1.82%	0.00%	5.20%	0.00%
1	0.24	3.00%	0.00%	1.82%	0.00%	5.00%	0.20%
1	0.26	3.00%	0.00%	1.82%	0.00%	5.00%	0.40%
1	0.28	3.00%	0.00%	1.82%	0.00%	5.00%	0.40%
1	0.30	3.00%	0.00%	1.82%	0.00%	4.60%	0.80%
1	0.32	3.00%	0.00%	1.82%	0.00%	4.60%	0.80%
1	0.34	2.50%	1.00%	1.82%	0.00%	4.60%	0.80%
1	0.36	2.50%	1.00%	1.82%	0.00%	4.60%	0.80%
1	0.38	2.50%	1.00%	1.82%	0.00%	4.60%	0.80%
1	0.40	2.50%	1.00%	1.82%	0.09%	4.60%	1.00%
1	0.42	2.50%	1.00%	1.82%	0.09%	4.60%	1.00%
1	0.44	2.50%	1.00%	1.82%	0.09%	4.60%	1.00%
1	0.46	2.50%	1.00%	1.82%	0.09%	4.60%	1.00%
1	0.48	2.50%	1.00%	1.82%	0.09%	4.40%	1.60%
1	0.50	2.50%	1.00%	1.82%	0.09%	4.20%	2.00%
1	0.52	2.50%	1.00%	1.73%	0.27%	4.00%	2.20%
1	0.54	2.00%	2.00%	1.64%	0.45%	3.80%	2.60%
1	0.56	2.00%	3.00%	1.64%	0.55%	3.60%	3.60%
1	0.58	1.50%	4.00%	1.64%	0.73%	3.40%	4.00%
1	0.60	1.00%	5.00%	1.64%	0.91%	3.20%	4.40%
1	0.62	1.00%	5.00%	1.64%	1.18%	3.20%	4.60%
1	0.64	1.00%	5.50%	1.64%	1.27%	3.20%	5.00%
1	0.66	1.00%	5.50%	1.64%	1.73%	2.80%	6.00%
1	0.68	1.00%	5.50%	1.64%	2.09%	2.80%	6.00%
1	0.70	1.00%	7.50%	1.64%	2.27%	2.20%	7.40%
1	0.72	1.00%	7.50%	1.45%	2.55%	2.20%	7.80%
1	0.74	1.00%	8.00%	1.45%	2.64%	2.00%	8.40%
1	0.76	1.00%	9.50%	1.36%	3.09%	1.80%	9.40%
1	0.78	1.00%	9.50%	1.27%	3.73%	1.80%	9.80%
1	0.80	1.00%	9.50%	1.18%	4.27%	1.60%	10.60%
1	0.82	1.00%	10.00%	1.09%	4.73%	1.40%	11.80%
1	0.84	1.00%	12.50%	1.09%	5.18%	1.00%	13.40%
1	0.86	1.00%	13.00%	1.00%	5.91%	0.80%	15.20%
1	0.88	0.50%	16.00%	0.91%	6.91%	0.80%	16.80%
2	0.10	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.12	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.14	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.16	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.18	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.20	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.22	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.24	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.26	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.28	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.30	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.32	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.34	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.36	3.00%	0.00%	0.36%	0.00%	2.00%	0.00%
2	0.38	3.00%	0.00%	0.36%	0.09%	2.00%	0.00%
2	0.40	3.00%	0.00%	0.36%	0.09%	2.00%	0.00%

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
2	0.42	3.00%	0.00%	0.36%	0.09%	2.00%	0.00%
2	0.44	3.00%	0.00%	0.36%	0.09%	2.00%	0.00%
2	0.46	3.00%	0.00%	0.36%	0.09%	2.00%	0.20%
2	0.48	3.00%	0.00%	0.36%	0.09%	2.00%	0.20%
2	0.50	3.00%	0.00%	0.36%	0.09%	2.00%	0.40%
2	0.52	3.00%	0.00%	0.36%	0.09%	2.00%	0.80%
2	0.54	3.00%	0.50%	0.36%	0.09%	2.00%	1.00%
2	0.56	2.50%	1.00%	0.36%	0.09%	2.00%	1.00%
2	0.58	2.50%	1.50%	0.36%	0.09%	2.00%	1.00%
2	0.60	2.50%	1.50%	0.36%	0.18%	2.00%	1.20%
2	0.62	2.50%	2.00%	0.36%	0.18%	2.00%	1.40%
2	0.64	2.00%	2.50%	0.36%	0.27%	2.00%	1.60%
2	0.66	2.00%	3.50%	0.27%	0.36%	1.80%	2.00%
2	0.68	2.00%	4.00%	0.27%	0.45%	1.60%	2.40%
2	0.70	2.00%	4.00%	0.27%	0.45%	1.40%	3.20%
2	0.72	2.00%	4.00%	0.18%	0.55%	1.20%	3.60%
2	0.74	2.00%	5.00%	0.18%	0.73%	0.80%	4.20%
2	0.76	2.00%	6.00%	0.18%	0.73%	0.80%	4.20%
2	0.78	2.00%	6.00%	0.18%	0.82%	0.80%	4.80%
2	0.80	2.00%	6.00%	0.18%	0.82%	0.80%	5.00%
2	0.82	1.50%	6.50%	0.18%	1.00%	0.80%	5.20%
2	0.84	1.00%	8.00%	0.18%	1.09%	0.80%	6.20%
2	0.86	1.00%	8.00%	0.18%	1.36%	0.40%	7.00%
2	0.88	1.00%	8.50%	0.18%	1.55%	0.40%	7.80%
3	0.10	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.12	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.14	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.16	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.18	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.20	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.22	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.24	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.26	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.28	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.30	8.50%	0.00%	0.64%	0.00%	5.20%	0.00%
3	0.32	8.50%	0.00%	0.64%	0.00%	5.20%	0.20%
3	0.34	8.00%	0.50%	0.64%	0.00%	5.20%	0.20%
3	0.36	8.00%	0.50%	0.64%	0.00%	5.20%	0.20%
3	0.38	8.00%	0.50%	0.64%	0.00%	5.20%	0.20%
3	0.40	8.00%	0.50%	0.64%	0.00%	5.00%	0.40%
3	0.42	8.00%	0.50%	0.64%	0.00%	4.80%	0.60%
3	0.44	8.00%	0.50%	0.64%	0.00%	4.80%	0.60%
3	0.46	8.00%	0.50%	0.64%	0.00%	4.80%	0.60%
3	0.48	8.00%	0.50%	0.64%	0.00%	4.80%	1.00%
3	0.50	7.50%	1.50%	0.64%	0.00%	4.60%	1.40%
3	0.52	7.50%	1.50%	0.64%	0.09%	4.20%	2.60%
3	0.54	7.50%	1.50%	0.64%	0.09%	4.20%	2.60%
3	0.56	7.50%	1.50%	0.55%	0.27%	4.20%	2.80%
3	0.58	7.50%	1.50%	0.45%	0.36%	4.20%	3.20%
3	0.60	7.50%	2.00%	0.45%	0.36%	4.00%	4.20%
3	0.62	7.00%	3.00%	0.45%	0.36%	4.00%	4.40%
3	0.64	7.00%	3.00%	0.45%	0.36%	4.00%	4.80%
3	0.66	6.50%	4.00%	0.45%	0.36%	4.00%	5.00%
3	0.68	6.00%	4.50%	0.45%	0.45%	3.80%	5.60%
3	0.70	5.50%	5.00%	0.45%	0.45%	3.40%	6.40%
3	0.72	5.50%	5.00%	0.36%	0.55%	3.40%	6.80%
3	0.74	5.00%	6.00%	0.36%	0.55%	3.20%	7.20%
3	0.76	5.00%	6.50%	0.27%	0.82%	3.00%	8.00%
3	0.78	4.50%	7.00%	0.27%	0.91%	3.00%	8.40%
3	0.80	4.50%	7.00%	0.09%	1.09%	2.80%	8.80%

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
3	0.82	4.00%	9.50%	0.09%	1.18%	2.40%	9.40%
3	0.84	3.00%	10.50%	0.09%	1.27%	2.20%	10.40%
3	0.86	3.00%	10.50%	0.09%	1.36%	2.20%	12.00%
3	0.88	2.50%	12.50%	0.09%	1.64%	1.60%	13.00%
4	0.10	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.12	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.14	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.16	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.18	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.20	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.22	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.24	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.26	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.28	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.30	2.00%	0.00%	0.09%	0.00%	1.60%	0.00%
4	0.32	2.00%	0.50%	0.09%	0.00%	1.40%	0.20%
4	0.34	2.00%	0.50%	0.09%	0.00%	1.40%	0.20%
4	0.36	2.00%	0.50%	0.09%	0.00%	1.40%	0.20%
4	0.38	2.00%	0.50%	0.09%	0.00%	1.40%	0.40%
4	0.40	2.00%	0.50%	0.09%	0.00%	1.40%	0.40%
4	0.42	1.50%	1.00%	0.09%	0.00%	1.40%	0.40%
4	0.44	1.50%	1.00%	0.09%	0.00%	1.40%	0.40%
4	0.46	1.50%	1.00%	0.09%	0.00%	1.40%	0.40%
4	0.48	1.50%	1.00%	0.09%	0.00%	1.20%	0.60%
4	0.50	1.50%	1.00%	0.09%	0.00%	1.20%	0.80%
4	0.52	1.50%	1.00%	0.09%	0.00%	1.20%	0.80%
4	0.54	1.50%	1.00%	0.09%	0.00%	1.20%	0.80%
4	0.56	1.50%	1.00%	0.09%	0.00%	1.20%	1.00%
4	0.58	1.50%	1.00%	0.00%	0.09%	1.20%	1.60%
4	0.60	1.50%	1.50%	0.00%	0.09%	1.20%	1.60%
4	0.62	0.50%	2.50%	0.00%	0.09%	1.20%	1.60%
4	0.64	0.50%	2.50%	0.00%	0.09%	1.00%	1.80%
4	0.66	0.00%	3.00%	0.00%	0.27%	1.00%	1.80%
4	0.68	0.00%	3.00%	0.00%	0.27%	1.00%	2.00%
4	0.70	0.00%	3.50%	0.00%	0.27%	1.00%	2.00%
4	0.72	0.00%	3.50%	0.00%	0.27%	1.00%	2.00%
4	0.74	0.00%	4.00%	0.00%	0.27%	0.80%	2.20%
4	0.76	0.00%	4.00%	0.00%	0.55%	0.80%	2.20%
4	0.78	0.00%	4.50%	0.00%	0.64%	0.80%	2.20%
4	0.80	0.00%	5.00%	0.00%	0.64%	0.80%	2.40%
4	0.82	0.00%	5.00%	0.00%	0.64%	0.80%	2.40%
4	0.84	0.00%	5.00%	0.00%	0.82%	0.80%	2.40%
4	0.86	0.00%	6.00%	0.00%	0.82%	0.80%	2.80%
4	0.88	0.00%	6.00%	0.00%	1.00%	0.60%	3.20%
5	0.10	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.12	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.14	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.16	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.18	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.20	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.22	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.24	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.26	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.28	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.30	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.32	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.34	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.36	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.38	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.40	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
5	0.42	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.44	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.46	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.48	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.50	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.52	0.00%	0.00%	0.82%	0.00%	1.60%	0.00%
5	0.54	0.00%	0.50%	0.82%	0.00%	1.60%	0.00%
5	0.56	0.00%	0.50%	0.82%	0.00%	1.40%	0.20%
5	0.58	0.00%	0.50%	0.82%	0.00%	1.40%	0.20%
5	0.60	0.00%	0.50%	0.82%	0.09%	1.40%	0.20%
5	0.62	0.00%	0.50%	0.73%	0.27%	1.40%	0.20%
5	0.64	0.00%	0.50%	0.64%	0.45%	1.20%	0.40%
5	0.66	0.00%	0.50%	0.64%	0.45%	1.20%	0.40%
5	0.68	0.00%	0.50%	0.64%	0.45%	1.20%	0.60%
5	0.70	0.00%	0.50%	0.45%	0.64%	1.00%	1.00%
5	0.72	0.00%	0.50%	0.45%	0.64%	1.00%	1.20%
5	0.74	0.00%	0.50%	0.45%	0.73%	0.80%	1.40%
5	0.76	0.00%	1.00%	0.36%	1.00%	0.60%	1.60%
5	0.78	0.00%	1.50%	0.36%	1.00%	0.60%	1.80%
5	0.80	0.00%	1.50%	0.36%	1.00%	0.40%	2.00%
5	0.82	0.00%	1.50%	0.36%	1.00%	0.40%	2.20%
5	0.84	0.00%	1.50%	0.27%	1.18%	0.40%	2.60%
5	0.86	0.00%	1.50%	0.18%	1.36%	0.40%	3.20%
5	0.88	0.00%	2.00%	0.18%	1.36%	0.40%	4.00%
6	0.10	6.00%	0.00%	0.18%	0.00%	5.60%	0.00%
6	0.12	6.00%	0.00%	0.18%	0.00%	5.60%	0.00%
6	0.14	6.00%	0.00%	0.18%	0.00%	5.60%	0.00%
6	0.16	6.00%	0.00%	0.18%	0.00%	5.60%	0.00%
6	0.18	6.00%	0.00%	0.18%	0.00%	5.60%	0.00%
6	0.20	6.00%	0.00%	0.18%	0.00%	5.60%	0.00%
6	0.22	6.00%	0.00%	0.18%	0.00%	5.60%	0.00%
6	0.24	6.00%	0.00%	0.18%	0.00%	5.40%	0.20%
6	0.26	6.00%	0.00%	0.18%	0.00%	5.40%	0.20%
6	0.28	6.00%	0.00%	0.18%	0.00%	5.40%	0.40%
6	0.30	6.00%	0.00%	0.18%	0.00%	5.20%	0.60%
6	0.32	6.00%	0.00%	0.18%	0.00%	5.20%	0.60%
6	0.34	6.00%	0.00%	0.18%	0.00%	4.60%	1.40%
6	0.36	6.00%	0.00%	0.18%	0.00%	4.60%	1.60%
6	0.38	6.00%	0.00%	0.18%	0.00%	4.40%	1.80%
6	0.40	6.00%	0.00%	0.18%	0.00%	4.40%	2.00%
6	0.42	6.00%	0.00%	0.18%	0.00%	4.20%	2.20%
6	0.44	6.00%	0.50%	0.18%	0.00%	4.20%	2.20%
6	0.46	5.50%	1.00%	0.18%	0.00%	4.20%	2.20%
6	0.48	5.50%	1.00%	0.18%	0.00%	4.20%	2.20%
6	0.50	5.50%	1.00%	0.18%	0.00%	4.00%	2.60%
6	0.52	5.50%	1.00%	0.18%	0.00%	3.80%	2.80%
6	0.54	5.50%	1.50%	0.09%	0.09%	3.40%	3.40%
6	0.56	5.00%	2.00%	0.09%	0.09%	3.40%	3.60%
6	0.58	5.00%	2.50%	0.09%	0.09%	3.20%	4.00%
6	0.60	5.00%	2.50%	0.09%	0.18%	3.20%	4.20%
6	0.62	5.00%	2.50%	0.09%	0.18%	3.20%	4.40%
6	0.64	5.00%	2.50%	0.09%	0.18%	3.20%	4.80%
6	0.66	5.00%	2.50%	0.09%	0.18%	3.00%	5.00%
6	0.68	4.50%	3.00%	0.09%	0.18%	2.80%	5.20%
6	0.70	4.00%	3.50%	0.09%	0.18%	2.60%	5.60%
6	0.72	4.00%	3.50%	0.09%	0.18%	2.60%	5.80%
6	0.74	3.50%	4.00%	0.09%	0.45%	1.80%	6.60%
6	0.76	3.50%	4.00%	0.09%	0.64%	1.60%	7.40%
6	0.78	3.50%	4.50%	0.09%	0.64%	1.60%	7.40%
6	0.80	3.50%	5.50%	0.09%	0.64%	1.40%	7.80%

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
6	0.82	3.00%	6.00%	0.09%	0.73%	1.40%	8.60%
6	0.84	3.00%	6.00%	0.09%	0.73%	1.20%	9.40%
6	0.86	2.50%	8.00%	0.09%	0.73%	0.80%	10.00%
6	0.88	2.50%	8.50%	0.00%	1.00%	0.80%	11.20%
7	0.10	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.12	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.14	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.16	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.18	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.20	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.22	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.24	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.26	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.28	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.30	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.32	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.34	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.36	1.50%	0.00%	0.00%	0.00%	0.20%	0.00%
7	0.38	1.00%	0.50%	0.00%	0.00%	0.20%	0.00%
7	0.40	1.00%	0.50%	0.00%	0.00%	0.20%	0.00%
7	0.42	1.00%	0.50%	0.00%	0.00%	0.20%	0.00%
7	0.44	1.00%	0.50%	0.00%	0.00%	0.20%	0.00%
7	0.46	1.00%	0.50%	0.00%	0.00%	0.20%	0.00%
7	0.48	0.50%	1.00%	0.00%	0.00%	0.20%	0.00%
7	0.50	0.50%	1.00%	0.00%	0.00%	0.20%	0.00%
7	0.52	0.00%	1.50%	0.00%	0.00%	0.20%	0.00%
7	0.54	0.00%	1.50%	0.00%	0.00%	0.00%	0.20%
7	0.56	0.00%	1.50%	0.00%	0.00%	0.00%	0.20%
7	0.58	0.00%	1.50%	0.00%	0.00%	0.00%	0.20%
7	0.60	0.00%	1.50%	0.00%	0.00%	0.00%	0.20%
7	0.62	0.00%	1.50%	0.00%	0.00%	0.00%	0.20%
7	0.64	0.00%	1.50%	0.00%	0.00%	0.00%	0.20%
7	0.66	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
7	0.68	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
7	0.70	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
7	0.72	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
7	0.74	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
7	0.76	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
7	0.78	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
7	0.80	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
7	0.82	0.00%	2.00%	0.00%	0.00%	0.00%	1.00%
7	0.84	0.00%	2.00%	0.00%	0.00%	0.00%	1.00%
7	0.86	0.00%	3.00%	0.00%	0.00%	0.00%	1.00%
7	0.88	0.00%	3.00%	0.00%	0.18%	0.00%	1.20%
8	0.10	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.12	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.14	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.16	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.18	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.20	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.22	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.24	0.50%	0.00%	0.00%	0.00%	0.20%	0.00%
8	0.26	0.50%	0.00%	0.00%	0.00%	0.00%	0.20%
8	0.28	0.50%	0.50%	0.00%	0.00%	0.00%	0.20%
8	0.30	0.50%	0.50%	0.00%	0.00%	0.00%	0.20%
8	0.32	0.50%	0.50%	0.00%	0.00%	0.00%	0.20%
8	0.34	0.50%	0.50%	0.00%	0.00%	0.00%	0.20%
8	0.36	0.50%	0.50%	0.00%	0.00%	0.00%	0.20%
8	0.38	0.00%	1.00%	0.00%	0.00%	0.00%	0.40%
8	0.40	0.00%	1.00%	0.00%	0.00%	0.00%	0.40%

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
8	0.42	0.00%	1.00%	0.00%	0.00%	0.00%	0.40%
8	0.44	0.00%	1.00%	0.00%	0.00%	0.00%	0.40%
8	0.46	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
8	0.48	0.00%	1.50%	0.00%	0.00%	0.00%	0.40%
8	0.50	0.00%	1.50%	0.00%	0.00%	0.00%	0.60%
8	0.52	0.00%	1.50%	0.00%	0.00%	0.00%	0.60%
8	0.54	0.00%	1.50%	0.00%	0.00%	0.00%	0.60%
8	0.56	0.00%	1.50%	0.00%	0.00%	0.00%	0.60%
8	0.58	0.00%	1.50%	0.00%	0.00%	0.00%	0.60%
8	0.60	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
8	0.62	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
8	0.64	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
8	0.66	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
8	0.68	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
8	0.70	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
8	0.72	0.00%	2.00%	0.00%	0.00%	0.00%	0.60%
8	0.74	0.00%	2.50%	0.00%	0.00%	0.00%	0.60%
8	0.76	0.00%	3.00%	0.00%	0.00%	0.00%	0.60%
8	0.78	0.00%	3.50%	0.00%	0.00%	0.00%	0.60%
8	0.80	0.00%	3.50%	0.00%	0.00%	0.00%	0.60%
8	0.82	0.00%	3.50%	0.00%	0.00%	0.00%	0.60%
8	0.84	0.00%	3.50%	0.00%	0.00%	0.00%	0.60%
8	0.86	0.00%	3.50%	0.00%	0.00%	0.00%	1.00%
8	0.88	0.00%	3.50%	0.00%	0.00%	0.00%	1.20%
9	0.10	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.12	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.14	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.16	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.18	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.20	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.22	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.24	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.26	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.28	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.30	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.32	3.50%	0.00%	0.64%	0.00%	2.60%	0.00%
9	0.34	3.50%	0.50%	0.64%	0.00%	2.60%	0.00%
9	0.36	3.50%	0.50%	0.64%	0.00%	2.60%	0.00%
9	0.38	3.00%	1.50%	0.64%	0.00%	2.60%	0.00%
9	0.40	2.50%	2.00%	0.64%	0.00%	2.60%	0.00%
9	0.42	2.50%	2.00%	0.64%	0.00%	2.60%	0.00%
9	0.44	2.00%	2.50%	0.64%	0.00%	2.60%	0.00%
9	0.46	2.00%	2.50%	0.64%	0.00%	2.60%	0.00%
9	0.48	2.00%	2.50%	0.64%	0.00%	2.60%	0.00%
9	0.50	2.00%	3.00%	0.55%	0.09%	2.60%	0.00%
9	0.52	2.00%	3.50%	0.55%	0.09%	2.60%	0.20%
9	0.54	2.00%	3.50%	0.45%	0.18%	2.40%	0.40%
9	0.56	1.50%	4.00%	0.36%	0.36%	2.20%	0.60%
9	0.58	1.50%	4.00%	0.36%	0.36%	2.00%	1.00%
9	0.60	1.50%	4.00%	0.36%	0.45%	1.60%	1.60%
9	0.62	1.50%	4.50%	0.36%	0.45%	1.20%	2.00%
9	0.64	1.50%	5.50%	0.18%	0.64%	1.00%	2.40%
9	0.66	1.50%	6.00%	0.18%	0.73%	1.00%	2.60%
9	0.68	1.50%	6.00%	0.18%	0.73%	1.00%	2.80%
9	0.70	1.50%	6.00%	0.09%	0.91%	1.00%	3.20%
9	0.72	1.50%	6.00%	0.09%	1.09%	1.00%	3.40%
9	0.74	1.50%	6.00%	0.09%	1.27%	0.80%	4.00%
9	0.76	1.50%	6.00%	0.09%	1.27%	0.40%	4.60%
9	0.78	1.50%	6.50%	0.09%	1.36%	0.40%	5.00%
9	0.80	1.50%	7.00%	0.09%	1.36%	0.40%	5.40%

Label	Threshold	Verifying Set		Training Set		Testing Set	
		Error	Rejection	Error	Rejection	Error	Rejection
9	0.82	1.00%	7.50%	0.09%	1.45%	0.40%	5.80%
9	0.84	1.00%	7.50%	0.09%	1.55%	0.20%	6.80%
9	0.86	1.00%	7.50%	0.09%	1.55%	0.20%	7.20%
9	0.88	1.00%	8.50%	0.09%	1.64%	0.20%	7.40%

G.1 Diagrams of rejection rate to error rate

Figures 34 to 43 illustrate rejection rate to error rate for each class in the training, verifying, and testing sets. Each diagram shows how the error rate is reduced when the rejection rate is increased by changing the rejection threshold. Every point represents one line in Table 17. The rejection threshold points are marked on the diagrams by a small circle for each dataset. These points are selected based on the strategy mentioned before, and can change based on specifications of a real world application.

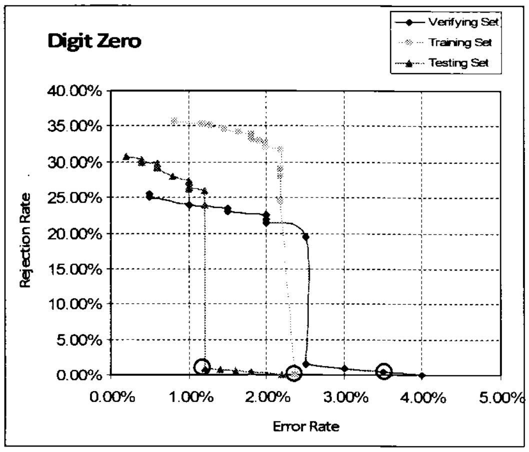


Figure 34 Rejection vs error Rate for digit Zero

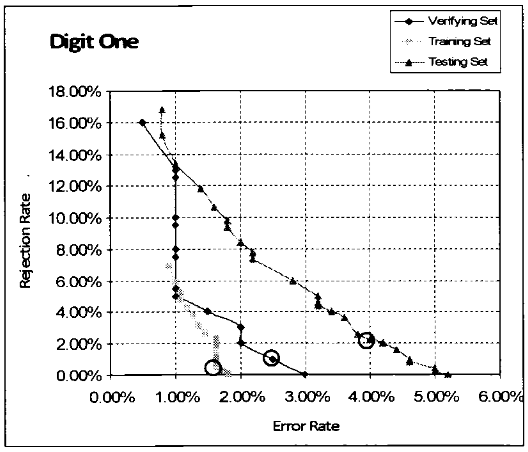


Figure 35 Rejection vs error rate for digit One

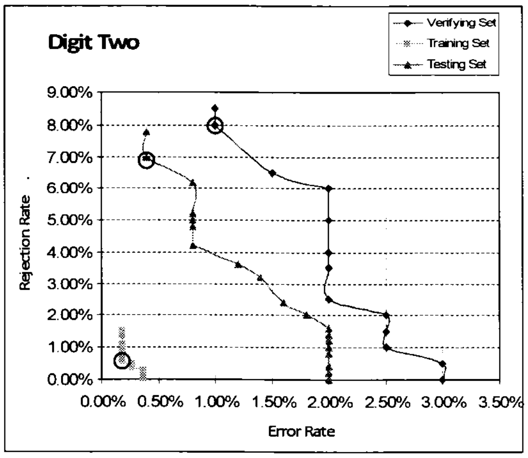


Figure 36 Rejection vs error Rate for digit Two

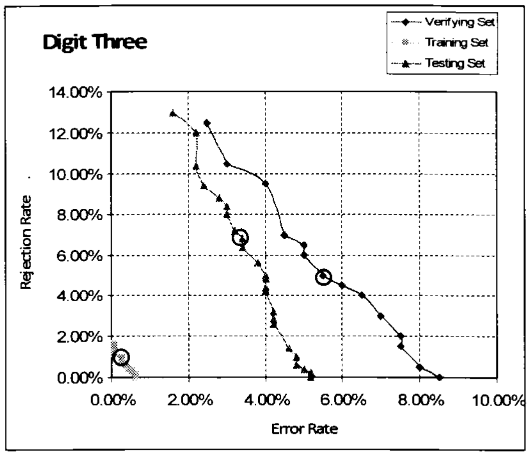


Figure 37 Rejection vs error rate for digit Three

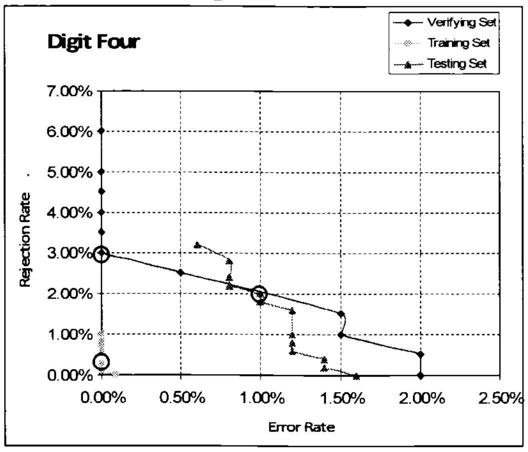


Figure 38 Rejection vs error Rate for digit Four

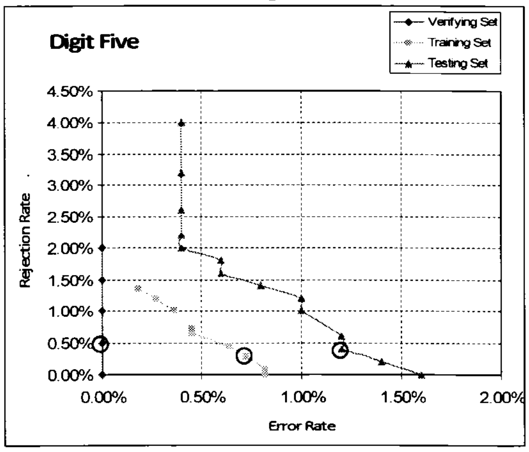


Figure 39 Rejection vs error rate for digit Five

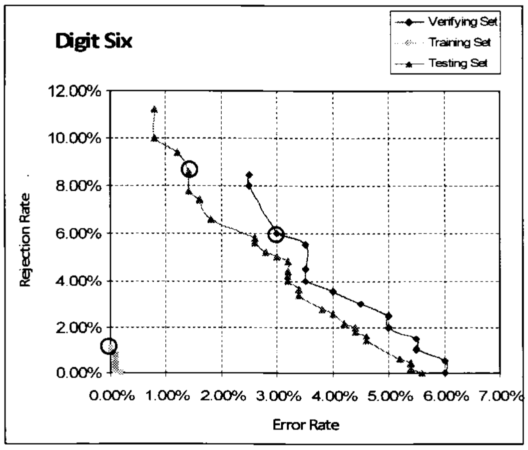


Figure 40 Rejection vs error Rate for digit Six

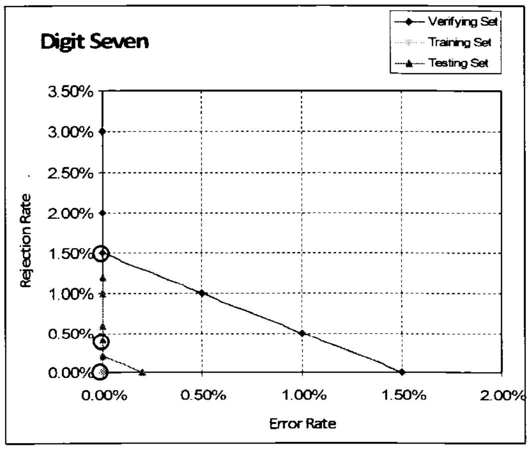


Figure 41 Rejection vs error rate for digit Seven

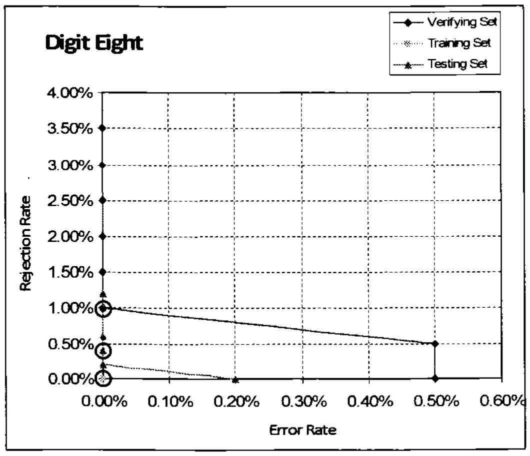


Figure 42 Rejection vs error Rate for digit Eight

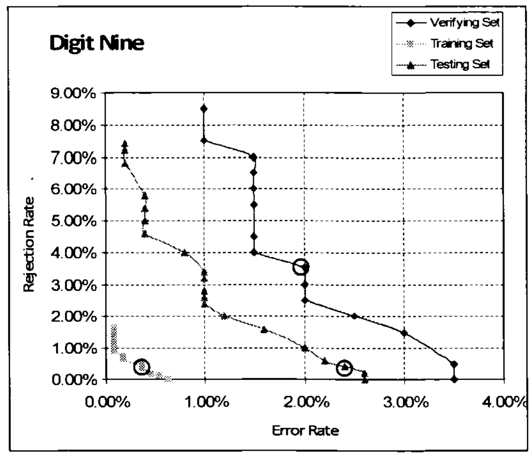


Figure 43 Rejection vs error rate for digit Nine