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Online handwriting Farsi character and number recognition based on hand movement direction using Hidden Markov Models

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Abstract—**Online handwriting recognition has many applications and the recognition with high accuracy is essential. In this paper, we introduce a method for online handwriting Farsi character and number recognition using Hidden Markov Models (HMM). First we recognize handwriting direction then we get some statistical and formatting features. The letters are classified by means of these features and then we use HMM for the recognition. We have some movements outside of the main body at the beginning or the end letters and number, so in this paper we put a Noise State at the beginning and end hmm and put an accepting state at the end to increase the recognition accuracy.We use Baum-Welch algorithm to introduce HMM and then give some samples. Note that the test results demonstrate the scalability of the proposed model and the recognition accuracy for numbers is 99.22% and for letters is 95.91%.**

Keywords- ***Baum-Welch algorithm; Forward algorithm; online handwriting Farsi character and numbers recognition; Hidden Markov Model (HMM)***

I. INTRODUCTION

One of the powerful cases of pattern recognition is handwriting recognition [14]. Handwriting recognition systems divided into two types of online and offline [1]. There are different methods for handwriting recognition, including statistical methods such as Hidden Markov Models and structural methods such as Neural Networks. There are reasons to take Handwriting recognition into consideration such as it is easier to write something than typing it, impossibility of typing in some places, and lack of existence of a full keyboard on some microcomputers [2]. Due to the specific features of Persian letters and dependency of Persian words on points, recognition of handwritten Farsi words is harder than recognizing English ones [8]. HMMs are now widely used in many languages to recognize handwritings[16]. In this paper, we obtain some statistical and formatting features and using HMM we perform the letter and number recognition andput a Noise State at the beginning and end hmm and put an accepting state at the end to increase the recognition accuracy.

II. RELATED WORKS

Handwriting recognition is one of the most interested topics in computer science. Handwriting recognition systems divided into two types of online and offline [1]. In the offline recognition scanned document image is used to get the data but in online recognition the entry of the system are the coordinates of points, pen direction and etc [3]. Many researches has been done about mentioned recognition methods. There are many more methods in those researches and one of important ones is HMM.

In [5], we propose a Bayesian network frame work for explicitly modeling strokes and their relationships of characters. A character is modeled as a composition of stroke models, and a stroke as a composition of point models. A point is modeled with 2-D Gaussian distribution for its X –Y position. Relationships between points and strokes are modeled as their positional dependencies. All the models and relationships are represented probabilistically in Bayesian networks. The recognition experiment with on-line handwritten digits showed promising results.

In [6], presents a novel fuzzy approach for recognizing online Persian handwriting which is also useful for multi-writer environments. In this approach, the representation of handwriting parameters is accomplished by fuzzy linguistic modeling. The representative features are selected to describe the shape of tokens. Fuzzy linguistic terms provide robustness against handwriting variations. The purposed method was run

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on a database of Persian isolated handwritten characters and achieved a relatively high recognition rate.

In [11], presents a comparative study of two machine learning techniques for recognizing handwritten Arabic words, where hidden Markov models (HMMs) and dynamic Bayesian networks (DBNs) were evaluated. The work proposed is divided into three stages, namely preprocessing, feature extraction and classification. Preprocessing includes baseline estimation and normalization as well as segmentation. In the second stage, features are extracted from each of the normalized words, where a set of new features for handwritten Arabic words is proposed, based on a sliding window approach moving across the mirrored word image. The third stage is for classification and recognition, where machine learning is applied using HMMs and DBNs. Experimental results and quantitative evaluations showed that HMM outperforms DBN in terms of higher recognition rate and lower complexity.

In [12], a hidden Markov model with parameter optimized k-means clustering is proposed for handwriting recognition. Two deep features of the images of characters are explored, thus significantly boosts the effectiveness of k-means clustering. The experiments show that this model largely increases the average accuracy of HMM with k-means clustering to 83.5% when the number of clusters is 3000.

In [7], fuzzy logic is used for online recognizing handwritten characters, first preprocessing is done on letters, then we use fuzzy classifier to recognize letters. The authors claim that recognition rate is 95% according to the data set used.

In [8], a concept for using point in a handwritten Arabic / Persian word is introduced, this concept presents a fast point-extractor method.

In [9], a segment-free approach for online Urdu handwriting recognition based on both HMM classifier and fuzzy logic is introduced. According to the authors claim, this technique which combines HMM and fuzzy logic is efficient for complex and large data set.

In [10] is introduced a mechanism to detect hand movement by means of HMM, note that a hand has four types of basic movements, namely, upward, downward, left and right movements, in the mentioned system, the authors consider that hand has eight kinds of movements, and they claim that this method, has a hand movement recognition rate of 97%. In many studies, hand movements divided into eight ones.

In [13],onlinehandwriting is diagnosed by a combination of horizontaland vertical trajectories. These trajectories are studied separately. In their work, some features offered for x (t) and y (t) signals and the features are used to make two separate classifiers. After the initial detection by the classifiers, the results are verified by the HMM classifier for final diagnostics.

In [15] integrates neural network models in decoding process and uses bidirectional neural networks, an amalgamation of HMMs, and extremely a combination of mentioned methods.

In [1] presents a method for recognizing online Persian characters based on HMMs. There, first the number of segments of letters is detected and by using the recognition for small parts the amount of candidate lettersare reduced, afterwards the body of unknown letter will preprocessed. The author's express recognitionaccuracy is 97.22%. In this method, the authors consider restrictions for point. By applying these restrictions recognition accuracy will reduce. In our proposed method, there is no restriction for recognition. We use the HMMs for our work.

III. RECOGNITION FRAMEWORK

Differentpeople have different handwriting;these differences maycause many problems inrecognition. Nowadays recognition with high precision is an essential requirement [1]. In this paper, for the recognizing Farsi letters and numbers online data set is used [4]. Based on hand movement direction in writing we work and we use HMMs for the recognition. We create the HMM based on hand movement direction when each letter and number is written.

A. Recognizing numbers

Online handwritten number recognition is based on hand movement direction. We restrict hand movements to eight movements [10] (Figure 1).

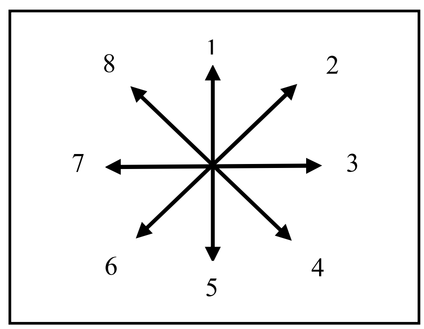

Figure 1. The hand movement direction

Some numbers have several customs in writing (Figure 2) and they direction in various forms are different (Figure 3), these differences reduce the accuracy of recognition. We make an HMM for each custom. We use HMM for recognition, and we create the model according to hand movement during writing each number. At the beginning and at the end of each Farsi number non-body movement may occur (Figure 4) thus at the beginning and end of each HMM put a state noise and place an accepting state. If each sample reaches to the agreement of related HMM, will produce. We use Baum-Welch algorithm to introduce HMM and then give some samples. Using samples entire HMMs are verified and the possibility of production of the sample will calculated by Forward Algorithm. The most possibility which obtained by HMM states that it is a number.

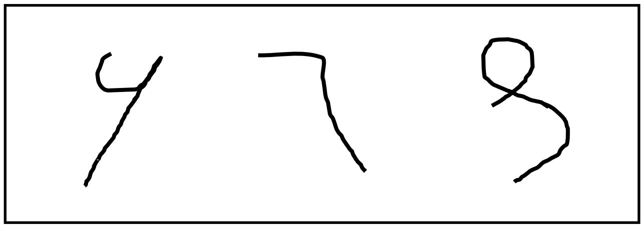

Figure 2. Different modes of writing the number 6

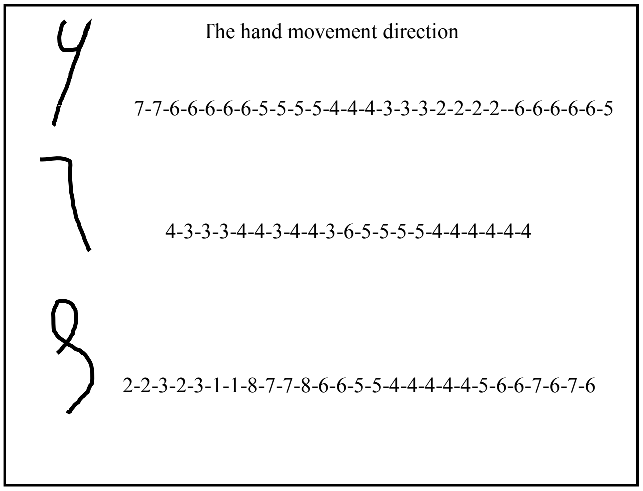

Figure 3. The hand movement direction in different modes of writingthe number 6

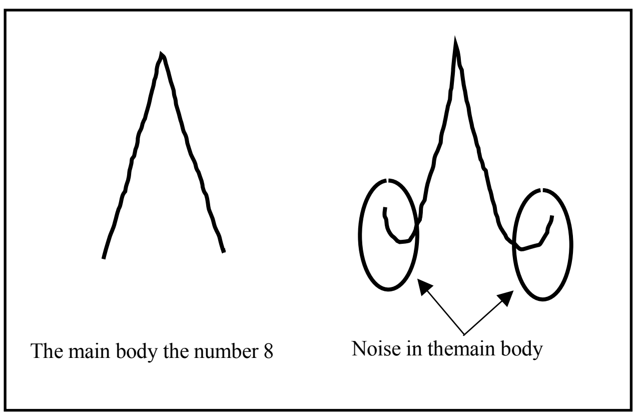

Figure 4. The main body the number 8 and available noise at the beginning and end the main body number 8

B. *Recognizing letters*

Farsi letters have statistical and formatting features. Formatting features which are used in this paper are the number of pen movements, which makes the letter be complete, the placement of additional characters relative to main letter body, and the sequence of direction of letters in writing. Statistical features include zoning and the ratio of height to width for letters [17].

1) *Feature Extraction*

We extract statistical and formatting features ofletters. First by means of data set [4], which contains the letters characteristics and handwritten numbers, we obtain hand movement direction for writing letters (Figure 6). Hand movements are restricted to eight move (Figure 1). We determine the amount of segments of letterwhich the movement of pen cause completeness of the letter [14], and the placement of additional character of each letter relative to each main letter body. Identifying the placement of the additional character is depended on the letter main body characteristics and or the extra part of the letter. Additional part commonly placed on the above or below of the main letter body. To determine the area occupied by each letter, we consider the distribution of the points of a specific place related to the whole letter. For this done, we use two lines which connects the middle of sides, thus four zones will made (Figure 5). Based on ratio of height over width, Farsi letters divided into three kinds namely oblique, vertical and horizontal [17] (Table I). We will not check these features for all letters. According to similarity of the direction of hand movement for each letter we check some of these features; Table (II) shows the investigation for each letter.

The ratio of height to width	***letter***
Horizontal	ا – آ – ل
Vertical	ب– پ– ت– ث–ف
Diagonal	Other letters

TABLE I. CLASSIFICATION OF CHARACTERS BASED ON THE RATIO OF HEIGHT TO WIDTH

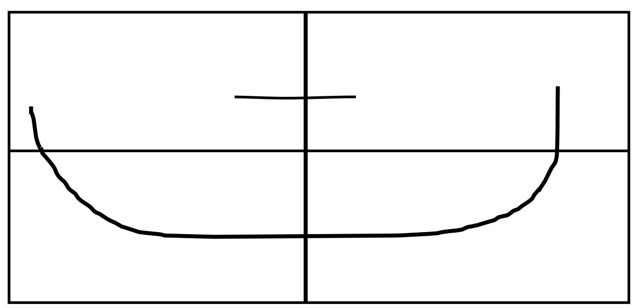

Figure 5. letters zoning

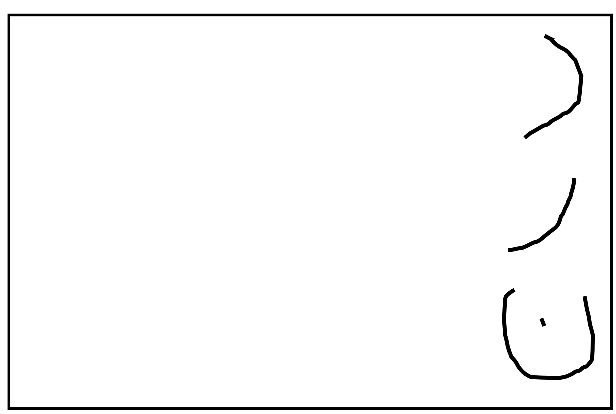

Figure 6. The hand movement direction in writing the letters'د','ر','ن'

2) Hidden Marcov Model

After the feature identification, we use HMM for letter recognition. There may some movements differ from main letter body, thus for increasing recognition accuracy, we in this paper, place a noise state at the beginning and at the end of each HMM and set an accepting state for each model. After the model created, we will use Baum-Welch algorithm to introduce the model with some samples. The entry will produced by the related HMM if reaches to accepting state. By entrance of each sample and verifying its features wecheck some HMMs. The possibility of production of each sample using HMM, will calculated by Forward Algorithm. More possibility which obtained from HMM states the letter.

IV. SIMULATION RESULTS

The proposed method implemented in the MATLAB programming environment. The proposed model examined for 1100 samples of numbers and 3630 samples of letters for online dataset [4]. Precision & Recall and F-measure tests applied to the test results for the numbers and letters. Table (III) shows the results obtained by Precision & Recall for the letters and numbers.Figure 7 shows the results for Precision & Recall and F-measure tests application on numeral system, it shows the accuracy of such examinations is 99.19%.Figure 8 involves Precision & Recall and F-measure tests application on letter system and has accuracy of 95.91%.The data in different scales are tested. The results show that the proposed model is scalable .Figure 9 shows the scalability results on the numbers and Figure 10 has scalability results on the letters.Because of similarity of hand movement in the letters (-ب پ), (ث-ت), (چ-ج), and (ژ-ز), it is hard to recognize these letters. Error tolerability of these letters are given in Figure 11.

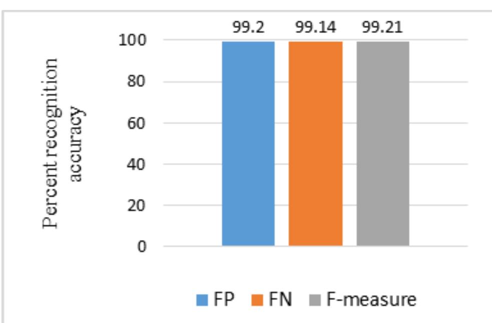

Figure 7. The results for FP,FN and F-measure tests on numeral system

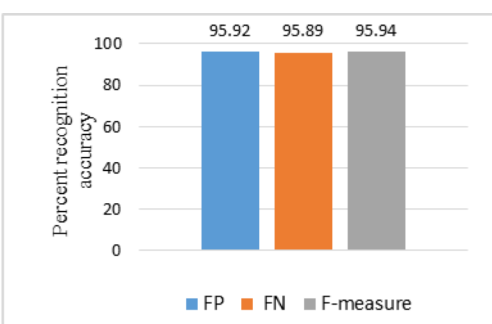

Figure 8. The results for FP, FN and F-measure tests on letters system

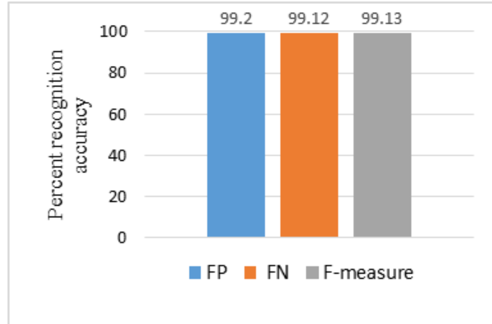

Figure 9. The scalability results on the numbers system

TABLE III. THE RESULTS OBTAINED BY PRECISION & RECALL TEST FOR THE LETTERS AND NUMBERS

Accuracy	*FN*	*FP*	*TP*	*letter*	*Accuracy*	*FN*	*FP*	*TP*	*letter*
100	2	0	110	غ	100	0	0	110	آ
100	0	0	110	ف	99	0	1	109	ا
88	22	13	97	ق	91	2	9	101	ب
100	6	0	110	ک	97	9	3	107	پ
99	18	1	109	گ	92	9	8	102	ت
100	2	0	110	ل	91	8	9	101	ث
100	0	0	110	م	96	5	4	106	ج
98	0	2	108	ن	95	5	5	105	چ
100	1	0	110	و	100	1	0	110	ح
98	1	2	108	ه	100	0	0	110	خ
100	0	0	110	ی	100	2	0	110	د
99	3	1	109	**0**	99	1	1	109	ذ
99	0	1	109	**1**	98	6	2	108	ر
99	0	1	109	**2**	97	27	3	107	ز
100	1	0	110	**3**	69	1	34	76	ژ
99	0	1	109	**4**	96	0	4	106	س
99	0	1	109	**5**	100	0	0	110	ش
98	2	2	108	**6**	100	4	0	110	ص
100	0	0	110	**7**	100	0	0	110	ض
100	1	0	110	**8**	76	10	26	84	ط
98	1	2	108	**9**	81	4	20	90	ظ
					98	0	2	108	ع

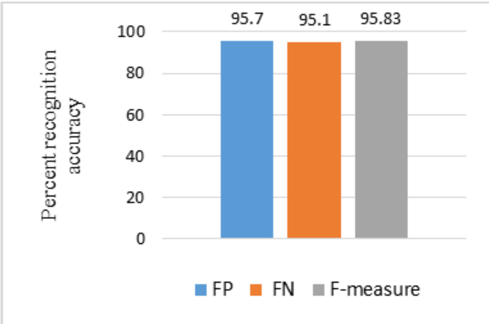

Figure 10. The scalability results on the letters system

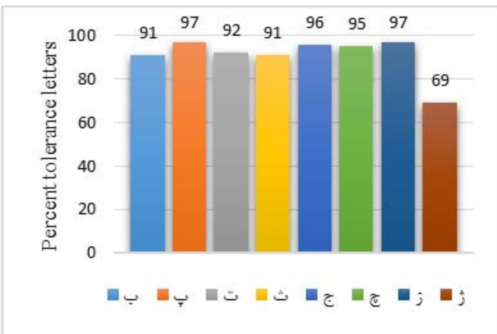

Figure 11. Error tolerability of letters (پ، ب),(ت، ث),(ج، چ),(ژ ، ز)

V. Conclusion

Different people have different handwriting, thus it is an essential need to accurately recognize writings with high precision. In this paper, we presented a method for recognizing Farsi numbers and letters using the HMM.We have some movements outside of the main body at the beginning or the end letters and number, so in this paper we put a Noise State at the beginning and end hmm and put an accepting state at the end to increase the recognition accuracy. Recognizing letters is based on some formatting and statistical features. Then the recognition is restricted on some letters to increase the recognition accuracy. We presume no restriction for writing letters and numbers. By the method application the rating of recognition is increased to some extent; note that the model is scalable. Results indicate that the recognition accuracy for the sample letters is 95.91% and for the sample numbers is 99.18%.

TABLE II. FEATURES FOR EACH LETTER IS CHECKED

				The sections of letters
س- ص			Zone 1, 3	1 Section
م			Zone 1, 2, 3	
ک- ط- ل- ر			Zone 1, 3, 4	
ا- ح- د- ع- و- ه- ی- ن			Zone 1, 2, 3, 4	
ش- ض		Zone 1, 3	The placement of additional characters relative to main letter body (Above the main body)	2 Section
ق- ک- گ- ط- ظ- ژ- ز	The ratio of height to width(Diagonal)	Zone 1, 3, 4		
ف	The ratio of height to width(vertical)	Zone 1, 3, 4		
خ- ذ- غ- ن	The ratio of height to width (Diagonal)	Zone 1, 2, 3, 4		
ت - ث	The ratio of height to width(vertical)			
آ	The ratio of height to width(Horizontal)			
ب- پ- ج- چ			The placement of additional characters relative to main letter body (Low the main body)	
ش		Zone 1, 3	The placement of additional characters relative to main letter body (Above the main body)	3 Section
ژ-گ- ق- ظ		Zone 1, 3, 4		
ت- ث		Zone 1, 2, 3, 4		
پ- چ			The placement of additional characters relative to main letter body (Low the main body)	
ث- ژ- ش			The placement of additional characters relative to main letter body (Above the main body)	4 Section
پ- چ			The placement of additional characters relative to main letter body (Low the main body)	

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