A Novel Method for Slant Correction of Persian Handwritten Digits and Words

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***Abstract*-- In this paper, a new slant estimation/correction method for Persian handwritten digits and words is presented. Based on the presented method, first using original image and its inversion, a new combined image is constructed. This new image has the same slant as the original image. So its slant is estimated and considered as the slant of original image. Finally, using a shear transformation, the slant of the original image is corrected. The performance of the presented method has been tested using several popular Persian/Arabic databases. Obtained experimental results and comparison with the other methods in the literature confirm that the presented method is accurate, and promising.**

Keywords— Slant estimation, Slant correction, Persian handwritten recognition, Handwritten digits, Handwritten words.

I. INTRODUCTION

Optical Character Recognition (OCR) is one of the main challenges in the field of pattern recognition [1]. An OCR system has three main modules: preprocessing, feature extraction, and classification. In the preprocessing module, some tasks are conducted in order to reduce the variations of the shapes of patterns to improve the performance of the next stages of an OCR system. Slant correction is considered as one of the main steps of preprocessing stage [2]. The deviation of digits and words from their vertical direction is called **slant** [3], [2]. Naturally, slant is found in all handwritten texts. Some samples of slanted Persian and Latin handwritten digits, letters, and words are shown in Fig. 1.

Handwriting recognition systems that do not use a slant correction method in their preprocessing stage, require much more data in order to learn cases of inclined patterns as much as possible [1]. Moreover, in these systems assigning a correct class to a given pattern (handwritten digit, letter, or word) is much more difficult since the number of possible classes is now bigger [4]. Therefore, in order to remove (or reduce) the influence of slant as much as possible, slant correction step should be applied before segmentation, feature extraction, training, or classification stage [2], [5]. It should be noted that the most of feature extraction, and classification methods are not slant invariant [5]. So, slant estimation/correction as an important module should be included in each OCR system in order to increase its performance.

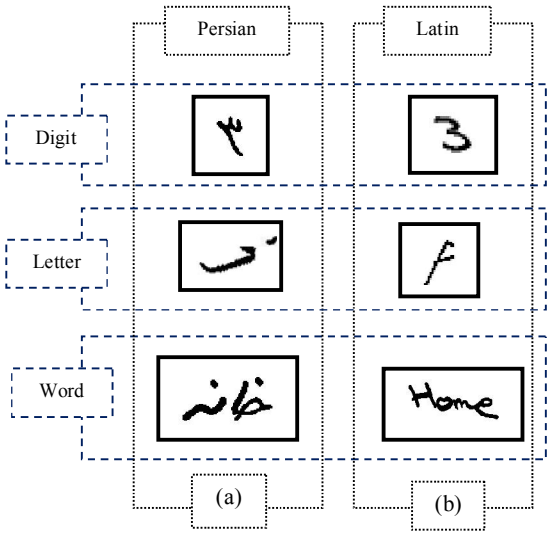

Fig.1. Some samples of slanted handwritten digits, letters, and words, in Persian (a), and Latin (b) scripts.

So far many attempts have been reported for estimation/correction of the slant of handwritings. Many of these conducted works have been presented for Latin handwritten digits [6], [7], numeral strings [2], and words [1], [8]. To the best of our knowledge, very few works have been conducted for estimation/correction of slant in Arabic ([9], [10]), and Persian ([4], [5]) scripts. Based on the method presented in [4], after an overall deslanting of the handwritten words, the remaining slant of each near vertical stroke is estimated using a non-uniform slant estimation. In [8], a slant estimation/correction method for Arabic handwritten words has been presented based on the center of gravity of each stork.

As mentioned above, the number of Latin attempts is really

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greater than Persian/Arabic works. However, it should be noted that due to the major differences between Latin and Persian/Arabic scripts [11], [12] many of Latin presented methods don't apply properly for Persian/Arabic handwritings. In this paper, a new method for estimation/correction of the slant of Persian handwritten digits and words is presented. The proposed method is a modified version of the method in [2].

The rest of this paper is organized as follows: the details of our slant correction method are explained in Section 2. In Section 3, the experimental results are presented. Section 4 is dedicated to the discussion and comparison. Finally, our conclusion and future works are drawn in Section 5.

II. OUR SLANT CORRECTION METHOD

The proposed slant correction method is a modified version of the method in [2]. Method in [2] was presented for slant correction for handwritten Latin numeral strings. In the following subsections, first we briefly review the method in [2], and then we explain our slant estimation/correction method.

A. Method presented in [2]

In [2], slant correction is conducted in two steps: first slant estimation, and then slant correction. First, input numeral string is divided into its Connected Components (CCs), and then as shown in Fig. 2, each CC is surrounded using the following four lines:

$$\begin{aligned} &L_1: y=x+\beta_1 \\ &L_2: y=x+\beta_2 \quad \beta_1<\beta_2 \\ &L_3: y=-x+\beta_3 \\ &L_4: y=-x+\beta_4 \quad \beta_3<\beta_4 \end{aligned} \tag{1}$$

Then slant angle (θ) of each CC is estimated using the following equation:

$$\theta=\arctan(B/A) \tag{2}$$

Where B is horizontal distance from point P to point Q, and A is the height of the CC, as shown in Fig. 2.

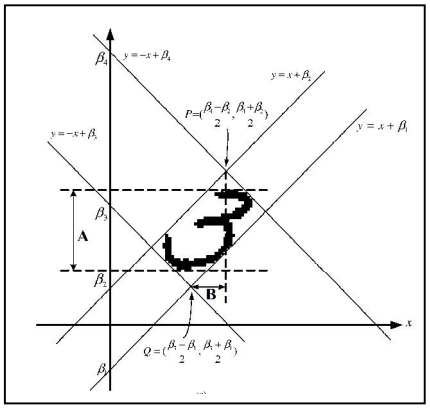


Fig.2. Details of method in [2]: a sample of Latin handwritten digit 3 as a Connected Component (CC) which is circumscribed using a tilted rectangle in order to compute its slant angle.

Finally, after estimating the slant, in order to correct the slant of a CC, a shear transformation in horizontal direction is applied to its image [2].

B. Our presented slant correction method

Due to the major differences between Latin and Persian handwritten digits [12] and based on the results of our experiments, although method presented in [2] is efficient and fast for handwritten Latin digits, it has lower performance for slant estimation of Persian handwritings and it needs to be modified. As an example, Fig. 3 shows the result of applying of this method to a sample of Persian handwritten digit 2. Based on the method in [2], slant angle of the image shown in Fig. 3(a) is estimated as $\theta\approx0^{\circ}$, and therefore the original image is not correctly deslanted, as shown in Fig. 3(b).

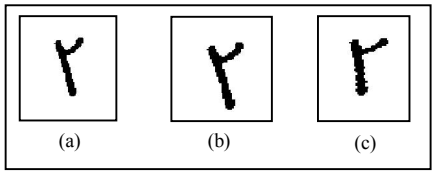


Fig.3. (a) Slanted image of Persian digit 2, and (b) output of applying method in [2] to (a), which is not correctly deslanted, and (c) result of applying our method to correct the slant of the image shown in (a).

According to the procedure of method in [2], and based on our experiments, it was found that this method has a better performance when the width of the top half of digit is approximately equal to the width of the bottom half of digit. Therefore, we modified the method in [2] as follows: at first using original image (Fig. 4(a)) of digit and its inversion (Fig. 4(b)), a new combined image (Fig. 4(c)) is constructed. The new combined image and the original digit image have the same slant angles (as shown in Fig. 4(c)). However, the width of the top half of combined image is truly equal with the width of the bottom half of its body. Then method in [2] is applied to the new image as shown in Fig. 4(d).

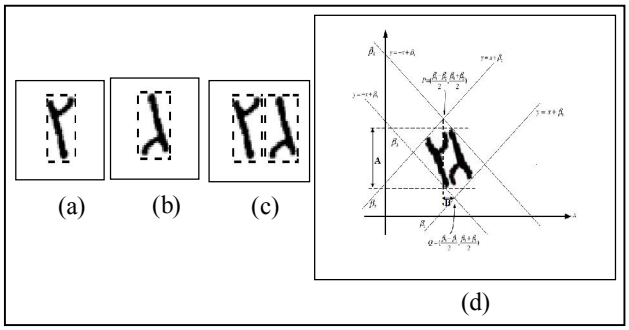


Fig.4. (a) Original image of Persian handwritten digit 2, (b) inversion of (a), (c) combination of (a), and (b) images, and (d) details of applying method in [2] to the combined image shown in (c).

After estimation of the slant angle, a shear transformation in horizontal direction is used to correct the slant of the original image. As an example, using our method, the slant angle of digit image shown in Fig. 3(a) (as the same image

shown in Fig. 4(a)) is estimated as $\theta \approx -12^{\circ}$, and its slant is properly corrected as shown in Fig. 3(c).

The procedure of constructing the new combined image related to the input image is conducted as follows: in the case of digit images, the inverted image is always positioned at the right side of the original image, similar to what was shown in Fig. 4. However, in the case of non-digit images, we consider a rectangle of size $M * N$ on the original image and its inversion, on their left sides. M is equal to the height of the bounding box of the image, and N is computed from $N = \lfloor M * \tan(\theta) \rfloor$, which θ is considered as a maximum slant angle i.e. 30°(as shown in Fig. 5). If the height of black pixels in the rectangle related to the original image is less than the height of black pixels in the rectangle related to the inverted image, then the inverted image is positioned at the left side of the original image (case A in Fig. 5). Otherwise, the inverted image is positioned at the right side of the original image (case B in Fig. 5). After construction the combined image, the method in [2] is applied to this image.

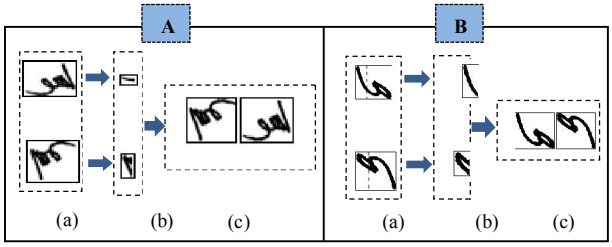


Fig.5. Construction of the combined image in two different cases: (A), and (B). In each case: (a) original non-digit image (top) and its inversion (bottom), (b) considered rectangles for decision about the position of the inverted image, and (c) final combined image.

It should be noted that based on our method, all input slanted images are segmented into their CCs and then our method has been applied on each CC, separately. The following remarks have been considered during applying our method to correct the slant of images of letters and words.

a) Persian alphabet has 32 letters which have been shown in Table 1. As shown in this table, 18 Persian letters have dots which appear on above or below of the baseline. Based on our method, dots are removed from the main body of image in question, and the presented slant correction method has been conducted on the main body of the characters.

b) As shown in Table 1, in the case of letters with upper cover like 'ک' (Kuf), and 'گ' (Guf), main body includes two sections. In these cases, the number of connected black pixels of second section is greater than $2/3$ of the first section. The slant of such these letters are considered as the slant of their greater section.

c) Another case which must be considered is that the main body of Persian letters such as: 'ر' (Reh), 'ز' (Zeh), 'ژ' (Zheh), and 'و' (Veh) originally written in tilted forms [4]. Therefore, by applying slant correction method, these letters be vertical erroneously, as shown in Fig. 6(a), and (b). Based on our experiments, the slant angles of handwritten Persian letters are not greater than 30 degree and in the most of cases, their slant angles are negative (as an example, image shown in the top of part (a) in Fig. 5(A) has negative slant angle as $\theta \approx -17.35$, and the slant angle of image shown in Fig. 6(a) is $\theta \approx 33.17$ as positive angle, based on our method). Therefore, we suggest that if the estimated slant angle (θ) of a letter is greater than 30 degree (which occurs in the cases: 'ر' (Reh), 'ز' (Zeh), 'ژ' (Zheh), and 'و' (Veh)), slant angle is considered as $\Phi = \theta - 45$, instead of θ, and slant correction method is applied using Φ. As shown in Fig. 6 applying our method using θ, make a deslanted letter falsely (Fig. 6(b)). But, the output of applying our method using Φ is truly deslanted as shown in Fig. 6(c).

TABLE I
ALL OF THE PERSIAN LETTERS, WHICH INCLUDE 18 DOTTED LETTERS (GRAY) AND TWO LETTERS WITH UPPER COVER (DARK GRAY).

Alef	Beh	Peh	The	Seh	Jeem	Cheh	He
ا	ب	پ	ت	ث	ج	چ	ح
Kheh	**Dul**	**Zul**	**Reh**	**Zeh**	**Zheh**	**Seen**	**Sheen**
خ	د	ذ	ر	ز	ژ	س	ش
Sud	**Zud**	**Tuh**	**Zuh**	**Ein**	**Ghain**	**Feh**	**Ghaf**
ص	ض	ط	ظ	ع	غ	ف	ق
Kuf	**Guf**	**Lum**	**Meem**	**Noon**	**Vuv**	**Heh**	**Yeh**
ک	گ	ل	م	ن	و	ه	ی

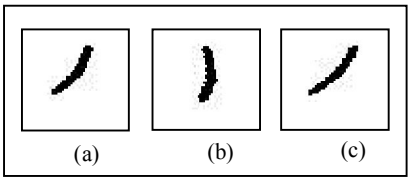


Fig. 6. (a) Original image of the slanted handwritten letter 'ر' (Reh), (b) falsely deslanted of (a) using $\theta \approx 33.17$ based on our method, (c) correctly deslanted of (a) using $\Phi (\theta - 45)$ based on our method.

d) It should be noted, that above mentioned procedures are used when the image of CC is a vertical image (i.e. when the height of bounding box of the CC is greater than its width). The performance of our method really decreased in the case of horizontal CC. Therefore, after recognizing a horizontal CC, the image of CC is rotated 90 degrees clockwise, and then our method applied to this new rotated image. As an example of this procedure see Fig. 7.

The procedure of applying the presented slant estimation/ correction method to a Persian handwritten numeral string and a word have been shown in Fig.8(A), and (B), respectively. Our experimental results have been presented in the next section.

III. EXPERIMENTAL RESULTS

In order to evaluate and compare the performance of the presented method for estimation/correction of slanted handwritten Persian digits, and words, we conducted several experiments on four popular Persian and Arabic handwritten digits and words databases. These databases are: Hoda [13] (Persian handwritten digits), IAUT/PHCN [14], [15] (Persian handwritten words), LOTRA [16] (Persian handwritten letters, and numeral strings), and IFN/ENIT [4], [17] (Arabic

handwritten words). Hoda's database includes 102,352 binary images of Persian handwritten digits which were extracted from 12,000 registration forms filled by B.Sc. and senior high school students [13]. We chose 900 digits images, randomly.

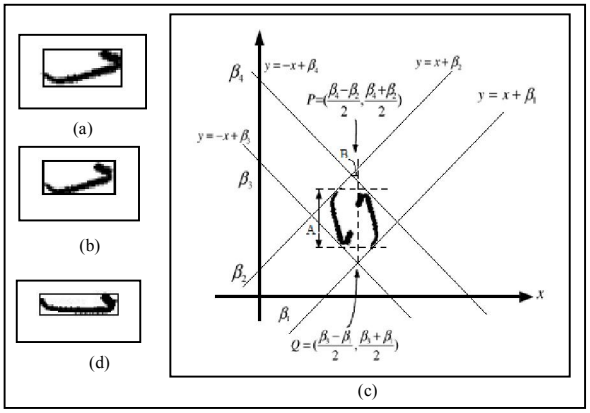


Fig.7. (a) Horizontal slanted Persian handwritten letter 'ف' (Feh) which its dot has been removed, (b) result of applying our method based on original image, (c) procedure of applying our method to the rotated image, and (d) result of applying procedure shown in (c).

IAUT/PHCN's database contains 34,200 binary images of handwritten Persian city names extracted from 1,140 forms which have been filled by 380 writers [14]. The numbers of930 words images have been chosen randomly. LOTRA's database includes 11,900 images of isolated letters, and 7,350 images of Persian handwritten numeral strings which have been written by 175 writers [16]. We chose 1,576 images of letters and 1,000 images of numeral strings images, randomly. IFN/ENIT's database contains 6,537 images of Arabic handwritten words [17]. The numbers of 567 words have been chosen, randomly. The numbers of chosen samples are shown in Table 2. It should be noted that in order to test the performance of the presented slant correction method, first original slant of randomly chosen samples of images from each of four mentioned databases, have been computed manually using exhaustive search method. Then the slant of each of these samples has been estimated using our presented method. Finally, comparison between the estimated and original slant angles is conducted and shown using five different histograms as Fig. 9. Also obtained error rates are computed as Mean Absolut Difference (MAD) [4], and shown in Table 3, for all databases. Some samples of each database before and after slant correction have been shown in Table 4.

Also for the first time, we conducted an experiment to see the potential of our method on free handwritten documents instead of isolated digits, and words. We applied our method to a free handwritten Persian text (including digits, words, numeral strings, and letters), as shown in Fig. 10(a). Obtained result (Fig. 10(b)) confirms that the proposed method has a very high potential for slant correction of all types of Persian handwritten documents.

TABLE II
The distribution of samples in four databases which have been used in our experiments.

DATABASE	TYPE OF HANDWRITTEN	NO. OF SAMPLES	NO. OF CHOSEN SAMPLES
HODA [13]	DIGIT (PERSIAN)	102,352	900
IAUT/PHCN [14]	WORD (PERSIAN)	34,200	930
LOTRA [16]	LETTER (PERSIAN)	11,900	1576
LOTRA [16]	NUMERAL STRING (PERSIA)	7,350	1000
IFN/ENIT [17]	WORD (ARABIC)	6,537	567

IV. DISCUSSION AND COMPARISON

In this section, we compare the performance of the presented method with only method found in the literature for slant estimation/correction of Persian/Arabic handwritten words [4]. Method in [4] was tested on the IFN/ENIT's database which includes images of handwritten Arabic words. In order to compare our method with method presented in [4], we apply our method on the samples of Arabic words which have been used in the experiments of method in [4]. Obtained results are drawn in Table 5. As shown in this table the performance of our method is as good as the performance of the method in [4]. However our presented method can be used for slant correction of all Persian handwritten digits, words, letters, and numeral strings with very high accuracy.

V. CONCLUSION AND FUTURE WORKS

A new method for estimation and correction for slanted Persian handwritten digits, and words was presented, in this paper. The presented method is a modified version of the method in [2], which was proposed for slant correction of Handwritten Latin numeral strings. According to our method, using original image and its inversion, a new combined image is constructed based on some proposed rules. Then by applying the method in [2] to the combined image (instead of original image), its slant angle is estimated and assigned to the original image. Finally, the slant of the original image is corrected, using a shear transformation. The performance of the presented method was evaluated using several popular databases: Hoda, IAUT/PHCN, LOTRA, and IFN/ENIT. Obtained experimental results confirm that the presented method has high performance compared to the similar methods. The presented method can be used in almost all Persian handwriting recognition systems such as: recognition of postal codes, courtesy amounts of bank checks, and etc., in order to increase their performances.

In the future, we are going to improve the performance of our method and apply to samples of Persian/Arabic historical documents.

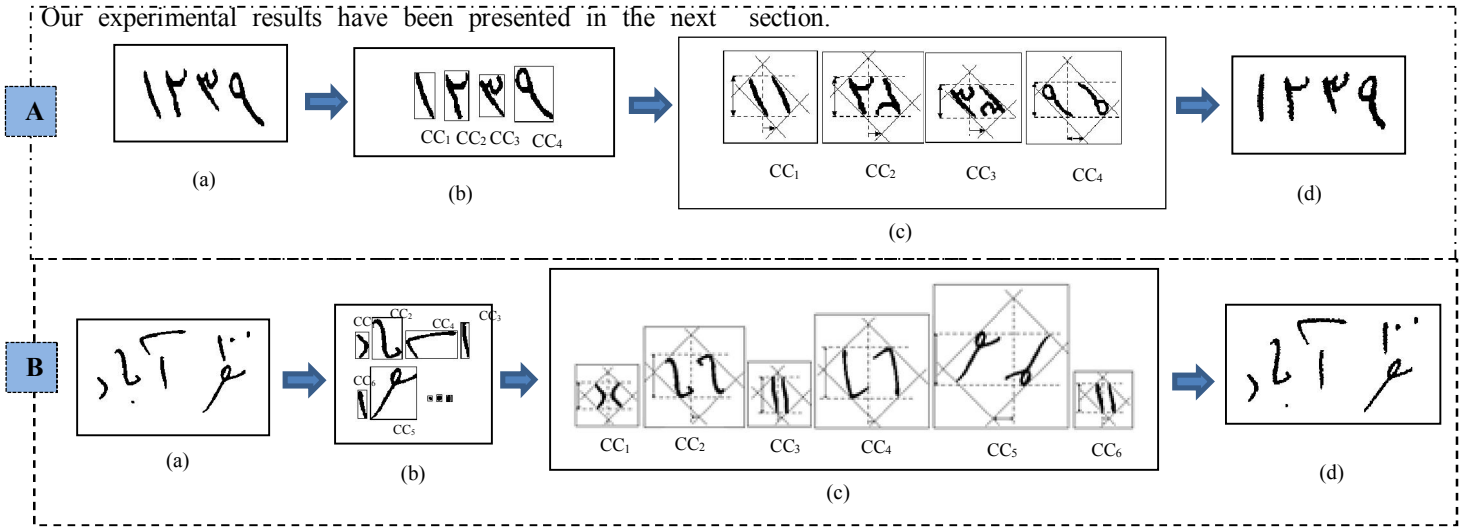


Fig.8. (a) The procedure of applying our slant correction method to a sample of handwritten Persian numeral string, and a word: (A), and (B), respectively

TABLE III
OBTAINED ERROR RATES OF ESTIMATED SLANTS WHICH HAVE BEEN PRESENTED AS MEAN ABSOLUT DIFFERENCE (MAD).

DATABASE (TYPE OF HANDRITINGS)	HODA (PERSIAN DIGIT)	IAUT/PHCN (PERSIAN WORD)	LOTRA (PERSIAN LETTER)	LOTRA (PERSIAN NUMERAL STRING)	IFN/ENIT (ARABIC WORD)
MEAN ABSOLUT DIFFERENCE (MAD)	2.7764	0.5329	1.5022	1.0668	0.4778

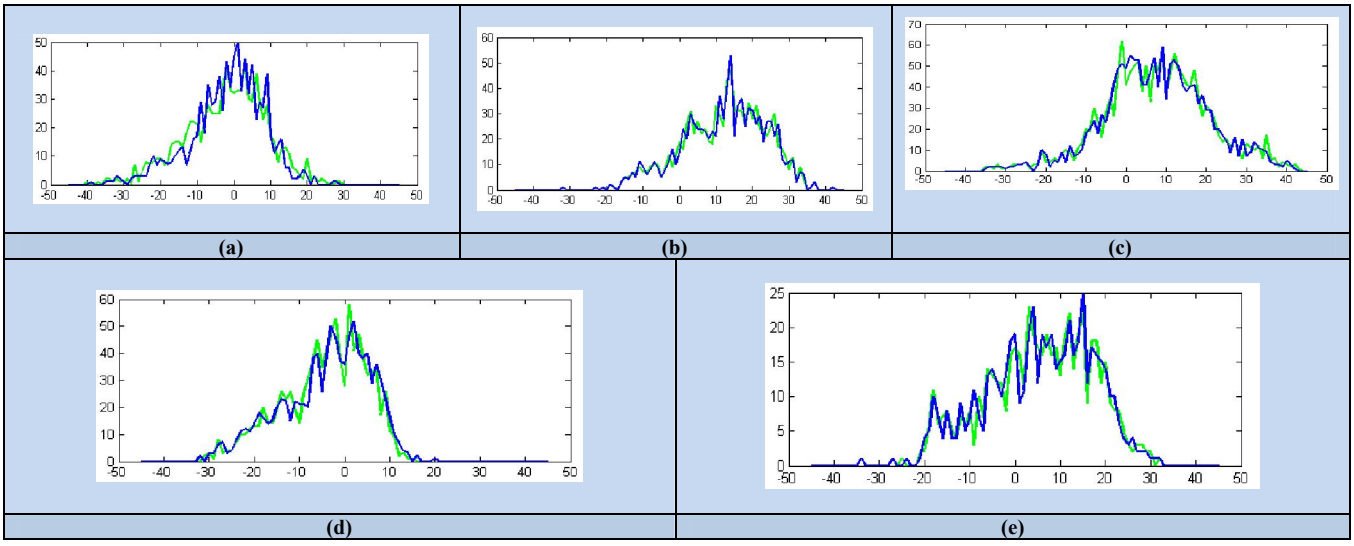
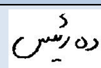
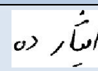
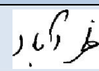
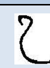
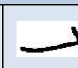
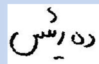
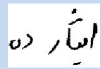
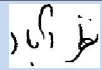


Fig.9. Histogram of the original (solid blue) and estimated (solid green) slant angles for: (a) 900 chosen digits from Hoda's database, (b) 930 Persian words from IAUT/PHCN database, (c) 1576 letters of LOTRA's database, (d) 1,000 numeral strings from LOTRA's database, and (e) 567 Arabic words from IFN/ ENIT's database.

TABLE IV
SOME SAMPLES OF IAMGES FROM EACH OF USED DATABASES BEFORE AND AFTER SLANT CORRECTION USING THE PRESENTED METHOD.

	Persian isolated digits			Persian words			Persian isolated letters		
Original image									
Deslanted image									
Estimated slant	-18.84	-15.06	-21.59	16.66	20.79	19.26	-14.23	-11.32	-15.58

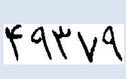
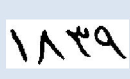
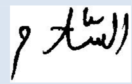
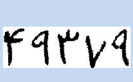
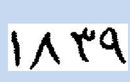
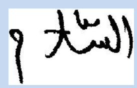
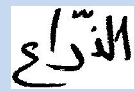
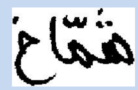
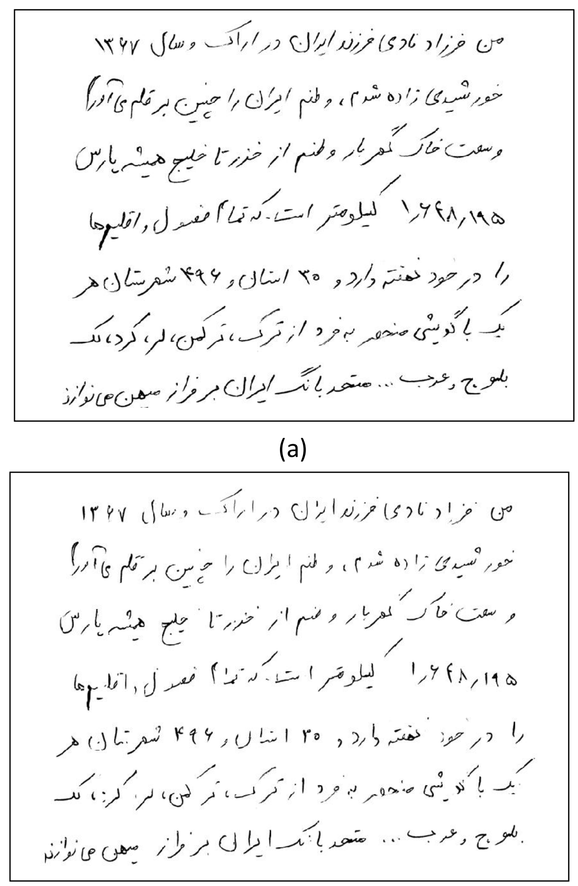
	Persian numeral strings			Arabic words		
Original image						
Deslanted image						
Estimated slant	-20.85	-29.74	-18.85	15.75	-17.04	-8.50

TABLE V
COMPARISON OF THE PERFORMANCE OF THE PRESENTED METHOD WITH THE RESULTS OF METHOD IN [4] ON SAMPLES FROM IFN/ENIT'S DATABASE.

Original images	Deslanted images based on method in [4]	Deslanted images based on the presented method
		



(a)

(b)

Fig. 10. (a) Original image of a free handwritten Persian text, (b) deslanted image of (a) using our presented slant correction method.

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