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Persian Handwritten Digit Recognition using Support Vector Machine

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Abstract: Handwritten digit recognition has a special importance and also different applications such as detecting handwritten addresses, cheques and documents. Persian handwritten digit classification is facing more difficulties due to different handwritten types and also inter-class similarities and intra-class differences. In this study, a method for Persian handwritten digits detection is proposing. In the proposed method, a mixture of Histogram of Oriented Gradients (HOG), 4-side profiles of the digit image and some horizontal and vertical samples of it is used. Then, the dimension of the feature vector is reduced by using Principle Component Analysis (PCA). In the classification step, Support Vector Machine (SVM) is used. The proposed method is applied on the HODA database. The results shows 99.25% in detection accuracy which is an adequate rate due to existing unacceptable samples in the database as well as achieving great improvement comparing to other existing methods.

INTRODUCTION

Automatic character recognition is an interesting problem. Handwritten digit recognition has a special importance in this way due to its different applications. Some of its different applications are including detecting handwritten addresses, cheques and other documents. Peoples' handwritten are varying in different cultures, hence local research is required. Persian is the main language of several countries such as Iran, Afghanistan and Tajikistan and it is spoken by >110 million peoples (Pan *et al*., 2009). Persian handwritten digits have different forms, shapes and sizes which makes it's recognition more challenging. As an example, although, the Persian and Arabic digits looks each other, peoples write them in different shapes.

Automatic Persian handwritten recognition faces different problems coming from their intra-class differences and inter-class similarities. Figure 1 is showing some of them.

Literature review: Several researches have been conducted on handwritten digit recognition in different languages with different results (Wang and Chuang, 2012; Labusch *et al*., 2008; Ciresan *et al*., 2010), some researches are also done on Persian digits. Soltanzadeh and Rahmati (2004) have proposed a method based on external profile of the Persian digit image as the main feature, concatenating by number of the image's cut-offs and also histogram of its projection in different directions. They've used Support Vector Machine (SVM) for classification and achieved 99.5% of recognition rate

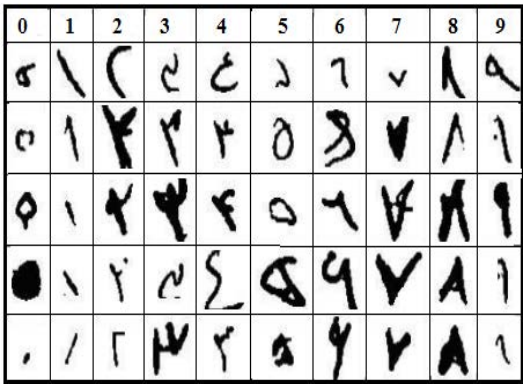

Fig. 1: Some Persian handwritten digits in different classes

by applying their method on a self-collected database. Nooraliei has proposed a method based on local features and histogram of image projection and using SVM by Nooraliei (2013). By applying their method on a dedicated database includes 8000 train and 600 test data samples which is distinguish between different forms of '4' and '6' digits, they've reached to 97.83% of accuracy. HODA is one of the most big and challenging datasets of Persian handwritten digits and characters which is used in many of researches in this area. This dataset includes 60000 training data samples and 20000 test ones. This dataset is used in this study. Alaei *et al*. (2009) have achieved to 98.71% accuracy by applying SVM on modified contour features of this database. Ebrahimpour *et al*. (2010) have proposed a two layer Radial Basis Function (RBF) neural network classification system in where four RBF classifier are applied on the image geometric description and an over-layer RBF neural network makes the final decision by weighting the previous ones. By applying their method on HODA database, they obtained 93.5% of accuracy. Abdi and Salimi (2010) have also proposed a similar mixed method and by applying Particle Swarm Optimization (PSO) method on the same dataset have get 97.1% of accuracy.

Histogram of Oriented Gradients (HOG) is a powerful feature extracting method which is frequently used in character and digit recognition algorithms in different languages (Kamble and Hegadi, 2015; Iamsa-at and Horata, 2013). It is also used in this research due to its good performance and specially, its robustness against image's dimension changing (Lowe, 2004). This algorithm is counting the number of edges in a local neighbor in the image (Dalal and Triggs, 2005). Gradient is calculating the magnitude and direction of the most changing pixels of the image (Ebrahimzadeh and Jampour, 2014). It is using Sobel filter as shown in Fig. 2

(a)

-1	0	1
-2	0	2
-1	0	1

(b)

1	2	1
0	0	2
-1	-2	-1

Fig. 2(a, b): Sobel mask used for gradient, (a) Horizontal and (b) Vertical

for horizontal and vertical components. Vertical and horizontal components can be calculated as following formulas:

$$G_x = H*I(x, y), G_y = H^T*I(x, y) \quad (1)$$

where '*' means correlation. Gradient of the image is calculating as:

$$G(x, y)=\sqrt{\left(G_x^2(x, y)+G_y^2(x, y)\right)} \quad (2)$$

And its direction as:

$$\theta(x, y) = \tan^{-1}\frac{G_x(x, y)}{G_y(x, y)} \quad (3)$$

HOG of the image is calculated by:

$$\Psi = \begin{cases} G(x, y), \text{ if } \theta(x, y) \in \text{bin}_k \\ 0, \quad \text{otherwise} \end{cases} \quad (4)$$

Verity of expert systems have been used for classification of handwritten characters or digits. Saxena have used neural networks for handwritten digits recognition. Support Vector Machines (SVM) is used frequently for this purpose and its excellency in handwritten digit recognition is shown by Ebrahimzadeh and Jampour (2014). Therefore, SVM is using in this research.

MATERIALS AND METHODS

As other pattern recognition methods, the proposed method can be divided into three major parts, namely pre-processing, feature extraction and classification, which will be discussed in following sections.

Pre-processing: One of HODA database problem is different size of its images. Furthermore, dimension ratio of different images are different inherently. For example, images of '1' or '9' are sketched vertically while '0' and

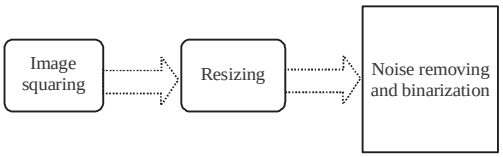

Fig. 3: Pre-processing steps

'5' images are more square shape. For overcoming this problem, the ratio of length and width of the image are calculated and some zero rows or columns will be padded to it symmetrically, in case that the ratio is <0.95 or >1.05.

In the second stage, the size of all images are adjusted, to generate unique block size and feature length by applying feature extractor algorithm. The final pre-processing part is noise reduction and Binarization of the images. Figure 3 is summarizing the pre-processing parts.

RESULTS AND DISCUSSION

Feature extraction: Several features are extracted from each image and concatenated together to build feature vector. They are HOG, 4-side profiles of the digit image and some horizontal and vertical samples. Figure 4 is showing some HOG features of a digit '8' images which are calculated by non-overlapping blocks and different sizes.

In this research [8 8] block size HOG is used where by increasing HOG bins into 18, the feature length is increased to 648.

Other feature used in this paper is 4-side profiles. For this purpose as shown in Figure 5, the distances of the image from all borders are calculate and padded to the feature vector as a 128 bit new features.

The final image features are some vertical and horizontal samples of the image. In this way, the image edges are extracted using morphological operators and then its samples across vertical and horizontal lines in 5, 15, 25 coordinates is padded to the feature vector.

By applying the previous feature extracting methods, the length of the feature vector is reached to 1160 bits. Principle Component Analysis (PCA) algorithm is used for reducing its dimension, to improve the total performance. In order to find the optimum PCA length, the entire algorithm is done several times over 2% of training data by different PCA length. Figure 6 is showing the final classification accuracy versos different PCA length. As expected by increasing the feature vector length, the classification accuracy is improved but after reaching its maximum values, it remains adequately constant. Therefore, the maximum point is selected as the optimum PCA length which is 763 bit for this experiment. This optimum length is used for other experiments which will be performed over entire training dataset.

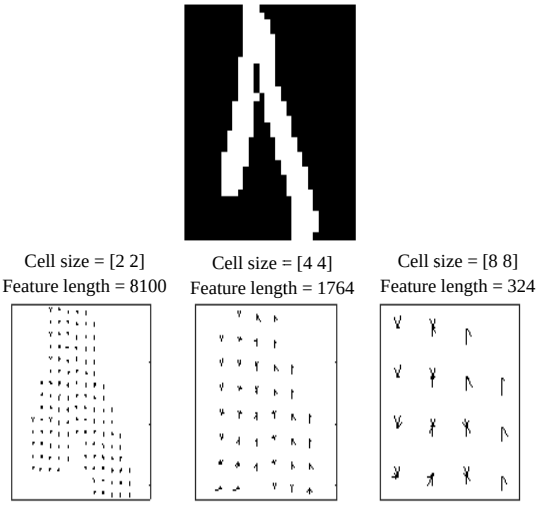

Fig. 4: HOG features of '8' image

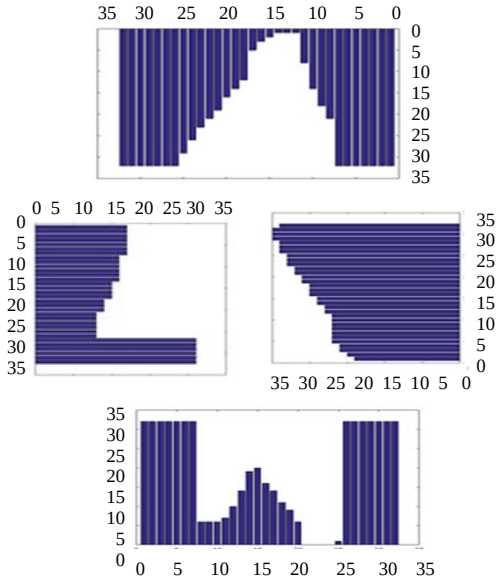

Fig. 5: The 4-side profiles of the '8' image

Classification: Different experts may be used for classification. In order to see the performance of them in Persian handwritten digits classifying, some famous algorithms are examined separately. In order to ensure the results, some of the experiments are performed several times by random train data samples. The results is shown in Table 1. As shown, SVM has the best classification accuracy over other methods. Different kernels can be used in SVM such as Linear, polynomial and Gaussian (RBF). All these kernels are examined in this research using the whole training data to find the best one. Table 2 is showing the results. As shown, the polynomial

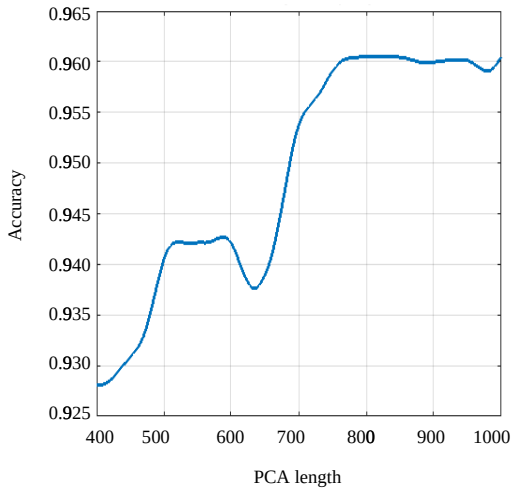

Fig. 6: PCA length analysing

Table 1: Some classification methods comparison

Learner	kNN	Tree	Discriminate	SVM
Detection accuracy	0.8875	0.8875	0.9125	0.9725

Table 2: Different SVM kernels comparison

SVM kernel function	Gaussian	Linear	Polynomial
Detection Accuracy	0.9868	0.9855	0.9925

kernel has the best classification accuracy in this usage as discussed and proof by Ebrahimzadeh and Jampour (2014).

As shown in Table 2, the best classification accuracy is achieved by applying polynomial SVM which is 99.25%.

CONCLUSION

Regarding importance of Persian handwritten digits recognition, a method for classifying them is introduced in this study. The proposed algorithm is based on applying SVM over a publicly available dataset name HODA.

In this way, a feature vector is extracted from each image using a mixture of different features. By reducing the dimension of the feature vector using PCA algorithm, its optimum length is calculated. Polynomial SVM is found to be the best classifier for this goal. By training it using train data and evaluating it, the overall classification accuracy is measured as 99.25% which shows improvement over prior methods.

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