Pattern Recognition Letters 93 (2017) 123–132

Contents lists available at ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

An efficient multiple classifier system for Arabic handwritten words recognition

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ARTICLE INFO

Article history:
Available online 31 January 2017

Keywords:
Arabic handwriting recognition
K-NN
MLP
SVM
ELM
Orthogonal moments (OM)
Chebyshev moments (CM)
Statistical and contour-based features (SCF)

ABSTRACT

In this paper, we propose an efficient multiple classifier system for Arabic handwritten words recognition. First, we use Chebyshev moments (CM) enhanced with some Statistical and Contour-based Features (SCF) for describing word images. Then, we combine several classifiers integrated at the decision level. We consider the multilayer perceptron (MLP), the support vector machine (SVM) and the Extreme Learning Machine (ELM) classifiers. We propose several combination rules between MLP, SVM and ELM classifiers trained with CM and SCF features. Further, we consider a second level of combination that merges three best rules among the proposed ones. The system is evaluated on the IFN/ENIT database and compared to some well-known systems for Arabic handwriting recognition. The numerical results are competitive and show that our system is able to achieve a global recognition rate equal to **96.82**% for the considered dataset.

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1. Introduction

Reading a handwritten script is often a difficult task which requires specialized skills. For instance, this difficulty can be noticed when reading a doctor's prescription without being a pharmacist.

When the goal is to achieve an automatic recognition system of a handwritten script, challenges are much stronger. There exist in the market several successful achievements on Latin and Chinese scripts but the Arabic language processing has been less lucky [4,5,35,42]. Although for more than thirty years, works on Arabic script have multiplied, the results are still shy and not enough conclusive. Much work remains to be done in the field [35,46,19,42].

Feature extraction is an important step in any handwriting recognition system since it permits to enhance the recognition performance. A large number of features have been used in handwriting recognition. Among them, we find moments, Fourier descriptors, wavelet analysis etc.

Moments are statistical descriptors concerned by all the pixels constituting the form to be recognized [8]. They include geometric moments (GM) and a variety of orthogonal moments (OM) [47]. Fourier descriptors with curvature scale space and shape signatures are only dedicated to the outline of the form. They use only the information on the forms' contours without considering interior pixels of the shape [40]. Handwriting recognition can be approached from two different angles [7,35,53,54]:

- Recognizing characters by using segmentation algorithms and then forming the words;
- Recognizing words as the basic units. In this case, segmentation is limited to demarcate the words in the handwritten text.

The present work deals with the second view.

First, we compare four moments which are common in the literature, in discriminating Arabic handwritten words. We use two continuous moments: Zernike and Legendre and two discrete ones namely Chebyshev and Krawchouk moments [8] in order to evaluate the impact of each moment on the recognition system. Second, we use some Statistical and Contour-based Features (SCF) to enhance the performance of the moments based features. We consider statistical features based on local information at the edges of the forms in order to be able to discriminate word images with globally similar shapes. Third, we propose several combination rules between MLP, SVM and ELM classifiers trained with CM and SCF features. We show that we can make the recognition system more effective by combining appropriate features with appropriate classifiers. The rules used in the combination of the classifiers are also compared to a learning combination technique performed by MLP and ELM classifiers.

Further, a second level of combination is achieved by using the results of the best combination rules. The different proposed techniques are implemented and evaluated on the IFN/ENIT database. A comparative study with some well-known techniques for

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http://dx.doi.org/10.1016/j.patrec.2017.01.020
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Arabic handwritten words recognition is done to evaluate the performance of our proposed system and to show its effectiveness.

The rest of the paper is organized as follows: Section 2 provides an overview of some of the concepts used in this study. It deals with the state of the art in the field of Arabic handwriting recognition, the moments and the classifiers used in this work. Section 3 details the proposed system. We present the statistical contour-based features, the combination rules and the way we trained an MLP and an ELM in the combination step. This section deals also with the second level of the achieved combination. Experiments and some numerical results are given in Section 4. Finally, Section 5 concludes and gives some perspectives for future works.

2. Background

This section starts with an overview of the Arabic handwriting recognition. Then we give a brief description of the moments and the classifiers used in this study.

2.1. Recognition of Arabic handwriting: a review

Arabic language is spoken by more than four hundred million speakers over the world. It has a standardized version called Modern Standard Arabic (MSA) that is read by much more people as it is the language used in the holy Quran and every Muslim is expected to read Quran as a part of his daily religious rituals. Arabic script is also used as a means to transcript other languages such as Persian, Kurdish, Malay, and Urdu. Thus, realize an automatic system that recognizes such a script is of great importance [4,7,46].

We focus the review on two important steps in a recognition system, namely the feature extraction and the classifiers combination. Several studies have used moments as feature extractors and showed a good performance in recognizing Arabic characters [2,6,12,41]. The Krawchouk moments have been used in [18] in describing IFN/ENIT words. Other techniques have been used in recognizing handwriting such as: Wavelet analysis [51], Gabor filter [20,51] and the Discrete cosine transform (DCT) [51]. The sliding window technique has been used for extracting local structural or statistical features, [4,35]. The structural features describe the topological and geometrical characteristics of the word. They include ascendants, descendants, loops, diacritics and their position relative to the baseline. The statistical features give some “measurements” of the word’s image such as the density of the writing in the whole image or in some regions of interest (ROI) in the image.

On the other hand, various classifiers have been used for Arabic handwriting recognition. Among them, we cite: HMM (hidden Markovian Models), ANN (Artificial Neural Networks) [1,3,4], LVQ (Learning Vector Quantization) [5], SVM (Support Vector Machines) [14,20], Fuzzy Min-Max Neural Network [12], Multidimensional Recurrent Neural Networks [22] and PGM (Probabilistic Graphical Models)[35]. However, to the best of our knowledge, there are only a few researches on Arabic handwriting words recognition using the ELM (Extreme Learning Machines) technique.

In the pattern recognition domain, the use of several classifiers on the same training sets and then combine their results for a better performance of the final system was the object of several works [56]. The first ones go up to the nineties of the last century [25,39]. This concept was also applied to the recognition of handwritten words [38,39]. The application to Arabic handwritten words is more recent [34,46]. Some of the recent works in the Handwriting Recognition field are summarized in Table 1.

2.2. The considered moments

When we project a function onto some harmonic basis we obtain Fourier coefficients as descriptors of the function. Similarly when we project the function onto a polynomial basis, we obtain scalars that are named moments. An image function (or image) is a real function $f(x, y)$ of two variables defined on a domain $D \subset R^2$ and having a finite nonzero integral. A general moment $M_{pq}(f)$ of an image $f(x, y)$ is given as:

$$M_{pq}(f) = \int\int_D P_{pq}(x, y) f(x, y) dxdy \quad (1)$$

Where p, q are non-negative integers and $r = p + q$ is called the order of the moment. $p_{00}(x, y), p_{10}(x, y), ..., p_{kj}(x, y), \ldots$ are polynomial basis functions defined on D. Moments are said to be orthogonal moments (OM) if:

$$\int\int_\Omega P_{pq}(x, y) P_{mn}(x, y) dxdy = 0 \quad (2)$$

or:

$$\int\int_\Omega w(x, y) P_{pq}(x, y) P_{mn}(x, y) dxdy = 0 \quad (3)$$

for any indexes $p \neq m$ *or* $q \neq n$. Eq. (2) denotes the orthogonality condition while Eq. (3) denotes the condition of weighted orthogonality. Unlike the geometric moments, OM moments give nonredundant and enhanced information to characterize the function. OM can also be computed by means of recurrent relations that permit to avoid using the terms of standard powers. For comparison purposes, we consider four moments commonly used in the literature, namely: Zernike, Legendre, Chebyshev and Krawchouk moments.

- Zernike moments have been introduced by Teague [8,17,45,50]. The polynomials are defined as:

$$V_{nm}(x, y) = V_{nm}(r, \theta) = R_{nm}(r) \exp j m\theta \quad (4)$$

where n is a positive integer or zero, m is an integer such as $n - |m|$ is even and $|m| \leq n$.

- Legendre moments are first introduced by Teague [8,33,47,55]. They were used in several pattern recognition systems [16,26]. They can provide a near zero value of redundancy measure, as they correspond to independent characteristics of the image.

- Chebyshev moments introduced by Mukundan [43] and expressed as: $T_n(x) = \cos(n.\arccos(x))$ are widely used for approximation purposes [10,52,57]. For a given function, one can generate the Chebyshev approximant such as $f(x) \approx \sum_{n=0}^{N} \alpha_n T_n(x)$, where T_n is a polynomial of degree n, and α is the expansion coefficient.

- Krawchouk moment are discrete by definition thus their implementation does not imply numerical approximation [18]. The definition of the n^{th} order Krawchouk polynomial with parameter p is given [7,10] by:

$$K_n(x; p, n) = \sum_{k=0}^{N} a_{k,n,p} x^k = {}_2F_1\left(-n, -x, -N; \frac{1}{p}\right) \quad (5)$$

where $x, n = 0, 1, 2, \ldots, N, N > 0, p \in [0, 1]$ and ${}_2F_1$ is the hyper geometric function. Krawchouk moments are able to extract local features of an image [18] by means of the parameter p that determines the *“localization”* of the polynomial in the interval [0, N]. If one knows a priori the area in the image where the most important information is localized, p can be chosen in such a way that the central part of the polynomial is shifted to this area. With no prior knowledge, a common choice is p = 0.5.

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