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A novel sparse model based forensic writer identification

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ABSTRACT

The paper presents a novel method for writer identification based on sparse representation of handwritten structural primitives, called *graphemes* or *fraglets*. The proposed method is different from the existing grapheme based methods as the earlier methods use vector quantization based coding (clustering method) to get a document descriptor, while the proposed method uses *sparse coding* for the same. Literature shows that the sparse coding outperforms vector quantization in many real life applications including face recognition. Sparse coding can achieve comparatively much lower reconstruction error. Secondly, the sparsity allows representation to be specialized and can capture a writer specific features more accurately. Graphemes (fraglets) extracted from a document are represented in terms of Fourier and wavelet descriptors because the fraglet contour may be well described by its global as well as local characteristics. Wavelet descriptors also give a multi-resolution representation of the shape. Results have shown that even with a smaller codebook (than the earlier reported systems), the proposed method achieves better performance.

1. Introduction

Authentication of a person based on his (her) handwriting is one of the oldest biometric hallmarks. Even in the modern digital era, handwriting based authentication is frequently used for legal and general official purposes. Research in the area of automated writer identification is more than three decades old and there are enormous literature available in this domain. Besides the extensive research in this domain, the large intra-writer variations (also called *natural variation* in forensic literature) has made this problem still open in pattern recognition framework.

One of the earliest researchers who has contributed towards systematic examination of questioned documents including writer recognition, though manual, is Osborne (1929). A comprehensive review of the work done before 1989 is given in Plamondon and Lorrete (1989). Recent findings of the work done in this domain, may be found in Bulacu and Schomaker (2007) and Plamondon and Srihari (2000).

Automatic writer identification is using one of the two strategies: (i) text dependent and (ii) text independent (Bulacu and Schomaker, 2007). The text dependent approaches are based on the semantic content of segmented characters/words/lines. And the respective characters/words/lines are sought for the identification, details may be found in Zois and Anastassopoulos (2000), Franke and Koppen (2001), Tomai et al. (2004), Srihari et al. (2002) and Zhang and Srihari (2003). Text independent approaches, on the other hand, do not depend on the semantic content. Text independent methods may also be attempted in one of the two ways: (i) whole document is considered as a text block and structural and textural features are extracted (Said et al., 1998; Marti et al., 2001; Hertel and Bunke, 2003) from the entire document/paragraph/line, or (ii) the grapheme based *codebooks* (Schomaker and Bulacu, 2004; Bensefia et al., 2005a,b; Bulacu and Schomaker, 2007) are prepared. In case of grapheme based method, content of the document is segmented into graphemes (or small fragments of text) and a codebook is prepared using some clustering techniques. Each of the fragments in the test document is then represented in terms of exactly one codeword (or fraglet) of the codebook (collection of fragments obtained from clustering). The histogram of codewords is used as a descriptor of the document and used for the identification purpose.

The main drawback of clustering based method is that each fragment of the document is represented by one and only one fraglet of the codebook. There may be situations when it is not possible to represent a fragment with exactly one fraglet of the codebook. The fact may be clear from the illustration shown in Fig. 1. One can see from the figure that the test fragment (*a*) can not be precisely represented by any of the fraglets shown in the codebook (*b*). This kind of problem may be avoided, at least for the given illustration, by taking a combination of some fraglets

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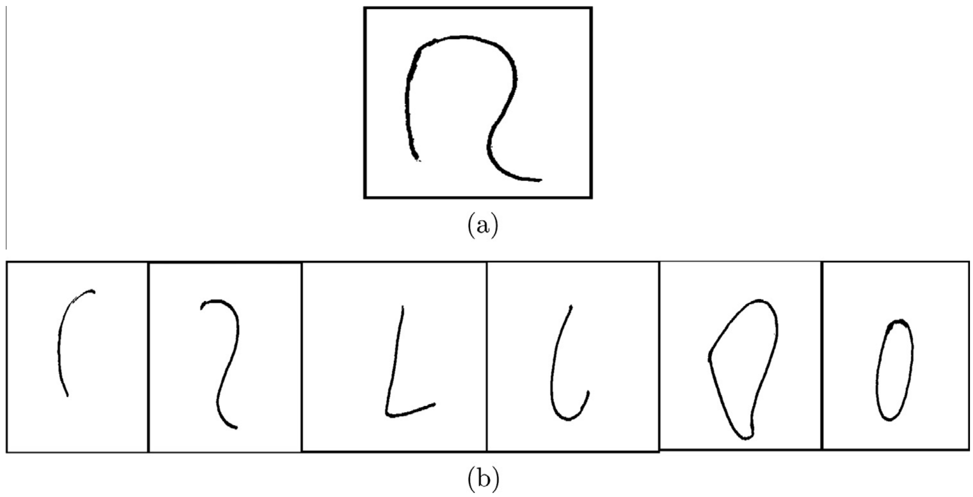

Fig. 1. Illustrates coding of fraglets. (a) Query fraglet and (b) codebook of fraglets.

present in the codebook. For example, the test fragment (a) of the figure may closely be represented as some combination of the first and the second fraglets of the codebook (b). Sparse coding is based on similar concepts.

The contributions of the present work are twofold; first, to propose a text independent writer identification system, which is based on sparse coding. The approach is based on the assumption that an individual writer generates a particular kind of structural primitives (graphemes or fraglets) and the writing habits of that particular writer can be represented as a combination of such structural primitives. Representation of graphemes as a combination of Fourier and wavelet coefficients may be considered as another significant contribution of the paper. By doing so the fragment signatures have got both global as well as local characteristics. Another advantage of such representation is that it can easily be made translation, rotation and scale invariant.

The paper is organized as follows: Sections 2 and 3 give a brief description of Fourier and wavelet descriptors and sparse coding respectively. The proposed writer identification system is discussed in Section 4. In Section 5, we discuss experimental results along with the description of the database used. Section 6 concludes the paper mentioning the scope of future work.

2. Fourier and wavelet descriptors

Shape is one of the best forms of visual information to describe an object. Various shape descriptors are reported in the literature, which are broadly classified as contour based features and region based features (Zhang and Lu, 2001). In case of handwritten samples, which are mostly in binary form, contour based features are found effective to represent the shape. Among contour based features, spectral descriptors like Fourier coefficients are popular ones. One of the advantages of the Fourier descriptors is that the first few low frequency coefficients of the Fourier transform capture the overall shape while the higher frequency terms capture its finer details. Besides, Fourier descriptors are easy to normalize (rotation, scale and translation) and preserve the overall shape information. In spite of so many advantages, Fourier descriptors fail to give multi-resolution representation. Wavelet descriptors, on the other hand, provide a multi-resolution representation and give a coarse-to-fine details of the shape. Unlike Fourier descriptors, wavelet descriptors achieve localization of shape feature in both spatial and frequency domains. We provide, next, a brief description of both Fourier and wavelet descriptors.

2.1. Fourier descriptors

A digital boundary, consisting of R points in an order (clockwise or anticlockwise), can be written as a sequence of complex numbers as $s(r) = x(r) + jy(r)$ for $r = 0, 1, \ldots, R-1$. Here, $(x(r), y(r))$, the coordinates of a contour point, is assumed to lie on a complex plane where x-axis is considered as real axis and y-axis as imaginary axis. The main advantage of this representation is that it converts a 2-D problem to a 1-D problem. The discrete Fourier transform (DFT) of $s(r)$ is

$$S(\upsilon) = \frac{1}{R}\sum_{r=0}^{R-1} s(r)e^{j2\pi\upsilon r/R}; \quad \upsilon = 0, 1, \ldots, R-1 \tag{1}$$

The complex coefficients $S(\upsilon)$s are called the Fourier descriptors of the contour. Details can be found in Gonzalez and Woods (2008). The main advantage of the Fourier descriptors is that we can make the descriptors rotation, translation and scale invariant using some simple operations. For example, by taking $|S(\upsilon)|$s, one can make the Fourier descriptors rotation invariant. Similarly, the descriptors can be made translation and scale invariant making first coefficient zero and one (by normalization) respectively.

2.2. Wavelet descriptors

Wavelets are the functions that are generated from a single function ψ, known as *mother wavelet*, by dyadic down sampling and translations (Antonini et al., 1992; Chang and Kuo, 1993). Based on the mother wavelet, the k-th generation daughter Haar wavelet may be defined as

$$\psi_{k,n}(r) = 2^{-k/2}\psi(2^{kr} - n) \tag{2}$$

where k and n are integers denoting scale and position respectively. Due to orthonormal property, the wavelet coefficients of a signal $f(r)$ can be easily computed via

$$F_{k,n}(r) = \sum_{r=0}^{R-1} f(r)\psi_{k,n}(r) \tag{3}$$

Here $f(r)$ represents the signature of grapheme, which is nothing but a sequence of distance of the contour points from its centroid $(\bar{x}, \bar{y})$, defined as $f(r) = \sqrt{(x(r)-\bar{x})^2 + (y(r)-\bar{y})^2}$ for $r = 0, 1, 2, \ldots, R-1$.