Feature Vector Extraction in HSV with Bandlet Transform

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***Abstract*—Handwritten Signature Verification (HSV) is a discipline which aims to validate the identity of writers according to the handwriting styles. Off-line HSVs compared with on-line ones are more adaptive in equipment involvement and can be applied in more fields, but more difficult to manipulate due to the loss of dynamic writing information such as writing position, velocity, acceleration and pressure. In this paper, we focus on off-line HSV and present a new feature extraction method based on Bandlet and fractal dimension, which gives full play to the merits of both conventional structure feature and statistical feature. After dimensionality reduction with K—L transform, genuine signatures and forgeries are distinguished with support vector machines (SVM). The experimental result confirms the effectiveness of our method.**

Keywords-Handwritten Signature Verification (HSV); feature vector extraction; bandlet transform; fractal dimension

I. INTRODUCTION

Handwritten signature verification (HSV) can be classified into two categories by input method [1]: on-line HSV and off-line HSV. The former relies on dynamic attributes, such as pressure, velocity and acceleration, and the latter deals with the digitized signature images. Since the information on time order and dynamics of writing process captured by the transducer device contains many useful writing features of the writer, on-line handwritten signature verification is easier to deal with and achieves a higher accuracy compared with off-line handwritten signature verification. But unfortunately, on-line system is inapplicable in many cases. Therefore, developing techniques on off-line handwritten signature verification has become an urgent task.

To tackle the problem, Sabourin and Drouhard [2] proposed an approach based on directional probability density function in combination with BP neural networks to detect random forgery. Bajaj and Chaudhury [3] proposed a system consisting of sub-classifiers based on three sets of global features. Sansone and Vento [4] proposed a sequential three-stage multi-expert system, in which the first expert eliminates random and simple forgeries, the second isolates skilled forgeries, and the third gives the final decision by combining decisions of the previous stages together with reliability estimations. However, its performance relies greatly on the rejection criteria chosen for each expert.

There are mainly two traditional methods for character feature extraction: structural feature and statistical feature. Structural feature includes cross point, contour, etc, while statistical feature includes point density, moment, characteristic region, etc. Based on the essential principle pointed out in [5], we combine the prior two kinds of features by virtue of Bandlet Transform (BT) and fractal dimension to extract feature vector, and apply it in off-line handwritten signature verification. In our algorithm, we capture rich direction information and self-similarity properties of signatures with Bandlet and fractal dimension, respectively.

II. BANDLET TRANSFORM

Bandelet transform is the representation method of images based on its edges, it can adaptively track geometry regular direction of the image. The specific steps of second generation Bandelet transform [6] is as follows:

(1) The multi-scale two-dimensional wavelet transform;

(2) With a Lagarange penalty function method for optimizing the objective function;

(3) The Quadtree segmentation and bottom-up harmony Cart algorithm, get the image multi-scale optimal Quadtree decomposition;

(4) According to the objective function, search for the optimal direction of profile control molecul-ar block in each direction of each layer (the optimal direction is parallel to the direction of the real geometry)

(5) Use an orthogonal direction perpendicular to the optimal direction projection and wavelet coefficients reordering to get one dimensional signal, and then to one dimensional wavelet transform.

III. FRACTAL DIMENSION

Historically, since F. Hausdorff(1919) introduced the term fractal dimension in the sense of non-integer dimension, the age of fractality has begun. Consequently, a set that can be assigned a fractal dimension is called a fractal set. One can determine the fractal dimension of the set by observing optimal covering systems of fractal sets with decreasing diameters. It should be mentioned that several different definitions of fractal dimension have been created since Hausdorff's paper and their relations are not simple. Here, we only introduce Box-Counting Dimension [7].

We define the box-counting dimension of a set S contained in n as follows: For any $\xi > 0$, let $j-th$ be the minimum number of n-dimensional cubes of side-length ξ to cover S. If there is a number d

$$N_{\xi}(S) \sim 1/\xi^{d} \quad as \quad \xi \to 0 \tag{1}$$

We say that the box-counting dimension of S is d. We will denote this by $S = d$. Note that the box-counting dimension is d. If there is some positive constant k so that

$$\lim_{\xi \to 0} \frac{N_{\xi}(S)}{1/\xi^{d}} = k \tag{2}$$

Since both sides of the equation above are positive, it will still hold if we take the logarithm of both sides to obtain

$$\lim_{\xi \to 0} (\ln N_{\xi}(S) + d \ln \xi) = \ln k \tag{3}$$

Solving for d gives

$$d = \lim_{\xi \to 0} \frac{\ln k - \ln N_{\xi}(S)}{\ln \xi} = -\lim_{\xi \to 0} \frac{\ln N_{\xi}(S)}{\ln \xi} \tag{4}$$

Note that the $\ln k$ term drops out, because it is constant while the denominator becomes infinite as $\xi \to 0$. Also, since $0 < \xi < 1$, $\ln \xi$ is negative, so d is positive as we would expect.

IV. PROPOSED SYSTEM

The proposed system for HSV involves two parts, training stage and testing stage, as is illustrated in Fig. 1.

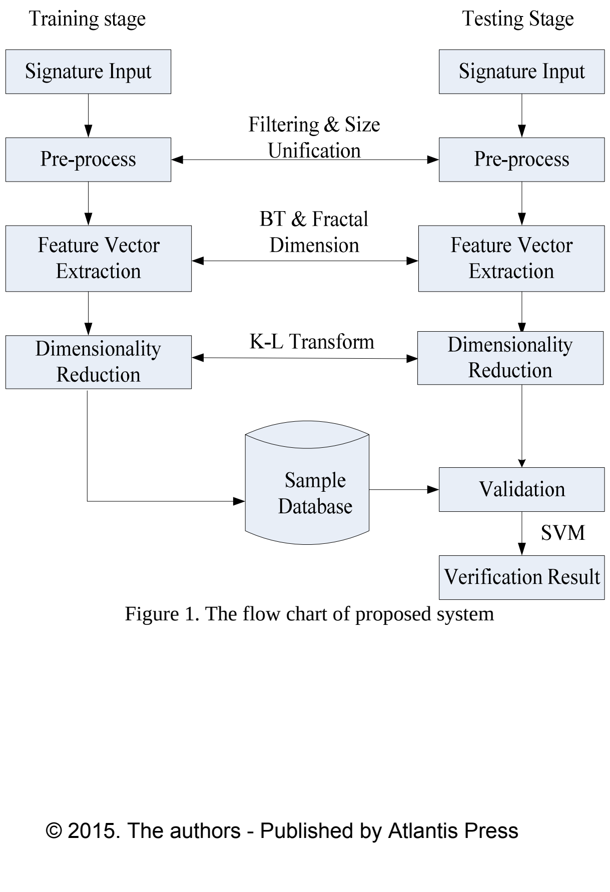

Figure 1. The flow chart of proposed system

V. EXTRACTING FEATURE VECTOR

Traditional signature verification feature vector extraction algorithms are mainly in the perspective of the overall image. With the deepening of research, feature vector extraction after direction decomposition is more suitable for Chinese characters than from the whole image. In this paper, we employ Bandelet transform, and the image is divided into seven block profile control molecule. Then according to the grid method in the feature extraction, the seven sub-bands of the second level decomposition is evenly divided into i blocks, and then calculate the average gray level N_i and fractal dimension M_i of each sub-block. The new statistical grid feature vector is:

$$F = \{N_i \quad M_i\} = [N_1 \quad M_1 \quad N_2 \quad M_2 \quad N_3 \quad M_3 ...] \tag{5}$$

Handwritten signature grid feature vectors increase the differentia of detailed characters of similar images, which is the detailed quantitative treatment of the Bandlet coefficients of handwritten signature, whose nature in math is independent vectors. The number of grid decides the dimensionality of feature vector. But with the increase of grid number, the dimensionality of feature vector will be lager, the design of classifier will be more difficult, and the result of identification is not always perfect. Therefore, we divide each sub-band of the second level decomposition into 8×8 blocks.

VI. EXPERIMENT

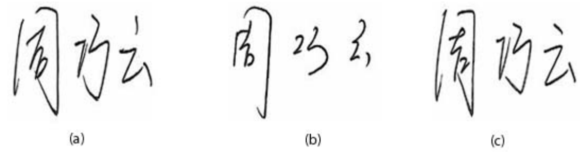

Figure 2 Signature samples: (a) genuine signature (b) random forgery (c) skilled forgery. The similarity between a and c is obviously higher than that between a and b, so the verification of c is more difficult

Signature samples are divided into two kinds of genuine signatures and forgeries, which are sub-divided into random forgeries and skilled forgeries. Because the genuine signature has not been seen, the random forgery is easy to verify. Meanwhile, the similarity between skilled forgery and genuine signature increases the difficulty of signature verification, as is shown in Fig. 2. In daily life, the number of random forgeries is larger and the detection of skilled forgeries poses more challenge.

Since there is no existing handwritten signature database available to us, we have to build a small database of this kind ourselves. Ours includes 400 signatures of 4 contributors, each contributing 50 genuine signatures, 30 skilled forgeries and 20 random forgeries. The signatures of each category are evenly separated into two sets, one for training and the other for testing.

TABLE 1. EXPERIMENT RESULTS (%)

Method	FAR (Random)	FAR (Skilled)	FAR	FRR	Total Error
Fourier	10	45	27	7	19
Entire Wavelet	7.5	35	24	5	14.5
Our Algorithm	5	10	8	2	5

The capability of the signature verification system is normally evaluated by two error rates——false rejection rate (FRR) and false acceptance rate (FAR). FRR is the rate of rejected genuine signatures, FAR is the rate of forgeries accepted. 600 feature vectors after dimensionality reduction are input SVM for training and testing. As shown in Table 1, our algorithm is better than other methods provided in [8].

VII. CONCLUSIONS

In this paper, we have presented a new feature vector extraction method on handwritten signature verification based on Bandlet and fractal dimension. Bandlet can capture comparatively richer directionality and geometric regularity, which is important to represent the writing style of a writer. With applying fractal dimension and grid thought to subbands of BT, we obtain the Bandlet grid feature vector, whose nature in math is independent vector. Compared with methods of Fourier Transform and Entire Wavelet, our algorithm obtains a higher accuracy.

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