signature recognition,
windows technique,
least squares contour alignment

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THE METHOD OF SIGNATURE RECOGNITION BASED ON LEAST SQUARES CONTOUR ALIGNMENT AND WINDOWS TECHNIQUE

This paper presents a new method of recognizing handwritten signatures. Signature was treated as a collection of features of specific values. As features the values of *x*, *y* coordinates of signature points have been used. The method discussed in the paper is a modification of the method based on least squares contour alignment. This modification consists of dividing signatures into windows of the preset size and measuring the value of similarity between the windows according to their position in the signature. The effectiveness of the method was verified in practice. During the study, the influence of the parameters of the method on the obtained results was determined.

1. INTRODUCTION

One of the longest known security techniques is signature biometrics. Biometrics can be defined as a method of personal identification, based on physical and behavioral features. Physiological biometrics includes data obtained directly from a measurement of a certain part of human body, such as a fingerprint, face shape or retina. On the other hand, behavioural biometrics analyses the data constituting a record of a way of behaviour of a given person, such as a manner of speaking, signature dynamics or features of pressing computer keyboard keys [1].

Handwritten signature is a result of a complex process, in which physical (fatigue, illness) and psychological (mood) factors of a signing person play a significant role. All these factors cause that a signature is characterized by significant variability and using it for verification or identification is not a trivial issue. For many years, problems of improving effectiveness of using signatures in identification and verification processes have been a subject of intense scientific studies and a challenge for many scientists dealing with biometric techniques of personal verification [1].

Nowadays there are a lot of methods of determining the similarity between signatures [3,6]. Their operation based on counting the distance e.g. Euclidean, Mahalanobis [2,7]. They can take advantage of various type of Neural Networks [5] or Hidden Markov Model [13]. There are also methods based on analysis of the object's features [8]. They consist of isolating points from the signatures (usually the points of edge or angles) and reducing the problem to match these points.

In this study, a measure of signature shape matching based on the least squares method was used for comparison of signatures. This method had already been used for this purpose. In the study [12], the least square method was used to determine the similarity of signatures on the basis of an analysis of their features, such as the coordinates signature points (*X*, *Y*), the pen pressure (*P*), the pen velocity (*Vx ,Vy*, *Vp)*. The studies showed that best results were obtained when analyzing shapes of signatures, that was the *X* and *Y* coordinates of signature points. This work is a continuation of mentioned research, therefore only the *X* and *Y* features were taken into account. In addition, a modification reducing the error of classification was made in the presented method. It was described in detail in a further part of this study.

2. LEAST SQUARES CONTOUR ALIGNMENT

Let's suppose that two sequences: $S=[s_1,s_2,...,s_n]$, $Q=[q_1,q_2,...,q_n]$ are given, which represent the same feature in two signatures being compared. Let's assume in addition the following assumptions:

- coordinates of signature points have been normalized to the interval [0, 1],

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- coordinates of the signature points have been centered, which means that:

$$\underset{i=1,\ldots,n}{\forall} s_i \in S,\ s_i = s_i - \frac{\sum_{j=1}^{n} s_j}{n}, \quad \underset{i=1,\ldots,n}{\forall} q_i \in Q,\ q_i = q_i - \frac{\sum_{j=1}^{n} q_j}{n}.$$

The distance between the S and Q features in the least square method is given by the following formula [8]:

$$d(S,Q) = \min_{t\in\mathbb{R}^2,\theta\in[-\pi,\pi),k>0} \left\| S - \Omega_{t,\theta,k}(Q) \right\|_F \tag{1}$$

where:

$\Omega_{a,\theta,k}$ – is the operator of translation by the vector $t \in \mathbb{R}^2$, rotation by the angle $\theta \in [-\pi, \pi)$, and scaling by the factor $k > 0$ [4],

$\left\| M \right\|_F$ – denotes the Frobenius norm of the matrix M.

The distance d (S, Q), given by the formula (1), is symmetric. This means that $d(S, Q)=d(Q, S)$. Formula (1) can be treated as a measure of similarity between two signatures. A detailed description of the least square method can be found in the work [8].

The least square method requires that the data being compared have the same number of elements. In the case of signatures, this condition is not always fulfilled, because the S and Q signatures may consist of different number of points. In work [12], two methods have been used for equalizing the number of signature points: the scaling and the DTW algorithm [9]. A characteristic feature of these methods is that they interfere with the input data (duplicate or remove existing signature points). In this study, a modification was made. It enables comparing signatures without affecting the data describing them. Determination of the similarity of signatures consists in comparison of corresponding signature parts (windows) with the same number of points. This method is described in the next section.

3. WINDOWS TECHNIQUE

The proposed method consists in dividing a signature into parts and calculating the value of similarity between individual parts. When comparing the S and the Q signatures, the sequence with the length of h successive points is analysed. In the further part of the study, it will be named "*window*" and designated as *win*. A division of the S signature into windows is shown in Fig. 1.

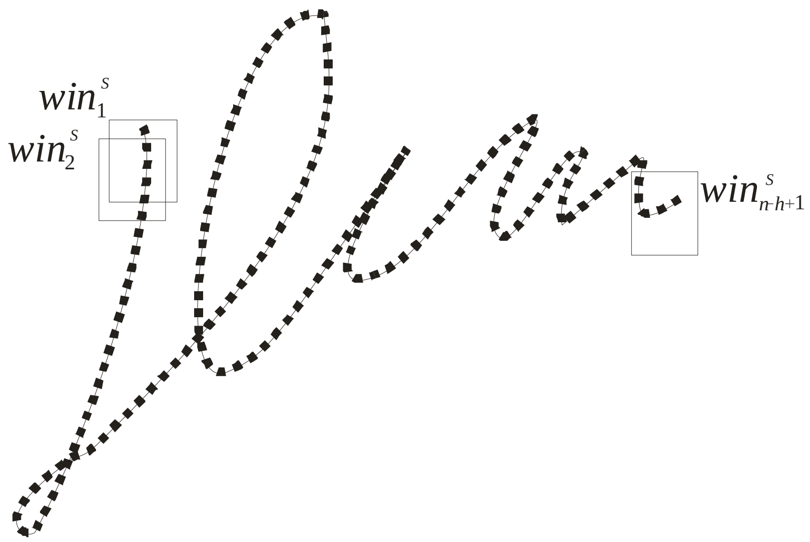

Fig. 1. Division of the S signature into windows, with the size (number of points) h=5 each.

The number of windows in a signature depends on the total number of signature points and assumed value of the *h* parameter. In a signature consisting of *n* points, the number of *win* windows, which can be created, is $L = n - h + 1$.

Successive windows in the *S* and *Q* signatures were defined by a certain number of points designated as jmp_s and jmp_q respectively. When determining the similarity of the signatures, individual windows in the *S* specimen signature are compared with all windows of the *Q* signature. For each pair of the windows being compared, their similarity $sim^{*h}_{i,j}$ is calculated:

$$sim^{*h}_{i,j} = d(win^S_i, win^Q_j) \tag{2}$$

where:

i	–	the number of the current window in the *S* signature,
j	–	the number of the current window in the *Q* signature,
h	–	the number of signature points in the area of the window,
$d(win^S_i, win^Q_j)$	–	distance between the compared windows in *S* and *Q* signatures computed by least square contour alignment method.

In order to speed up the method, another modification was introduced, which consisted in the possibility of setting the range of the windows being compared in *S* and *Q* signatures._Windows are compared with each other, if their distance *dist* is smaller than a certain defined value or equals this value. In the further part of the study, this value is designated as *maxdist*. The distance is calculated using the following formula:

$$dist(win^S_i, win^Q_j) = \begin{cases} 0, & dist^*(win^S_i, win^Q_j) < maxdist \\ dist^*(win^S_i, win^Q_j), & dist^*(win^S_i, win^Q_j) \geq maxdist \end{cases} \tag{3}$$

where:
maxdist – the maximum distance between the windows being compared,

$dist^*(win^S_i, win^Q_j) = 1 - \left| \dfrac{i}{L^S} - \dfrac{j}{L^Q} \right|$,

L^S – the number of all windows created in the *S* signature,
L^Q – the number of all windows created in the *Q* signature.

After the aforementioned modifications have been taken into account, the formula for the similarity between any two windows of the *S* and *Q* signatures is given in the following form:

$$sim^h_{i,j} = sim^{*h}_{i,j} \cdot dist(win^S_i, win^Q_j) \tag{4}$$

A single window *i* in the *S* signature is compared with each window in the *Q* signature. As a result of such a comparison, the SIM_i set of values of similarities between *i* window of the *S* signature and all windows of the *Q* signature is received.

$$SIM_i = \left\{ sim^h_{i,1}, sim^h_{i,2}, ..., sim^h_{i,L^Q} \right\} \tag{5}$$

After the similarity between all windows in the two signatures has been determined, the total similarity *WS* of the *S* and *Q* signatures can finally determined:

$$WS(S,Q) = \frac{1}{L^S} \sum_{i=1}^{L^S} \max(SIM_i) \tag{6}$$

A detailed description of the windows technique can be found in [10, 11].

4. RESULTS

The studies were conducted for 140 signatures coming from different persons. The signatures were divided into 20 groups. Each group contained 5 original signatures of one person and 2 forged signature. The set of test signatures used in the studies comes from the SVC2004 database (Signature Verification Competition – *http://www.cse.ust.hk/svc2004/index.html*). During the studies, various values of the *h*, *maxdist* and *jmp* parameters were checked. For one set of parameters, the total number of comparisons was 9730, which results from the assumption that comparisons of the following types are to be excluded:

- $a \to a$,
- $b \to a$, if the $a \to b$ comparison was performed.

In the next stage of investigations the well known the false rejection rate (FRR), the false acceptance rate (FAR), and the equal error rate (EER) have been used as quality performance measures. The FRR is used for genuine signatures and the FAR for forgery signatures. Because these two factors are inversely related, the EER factor is often reported. Table 1 presents best results, taking into account the values of parameters of the method.

Table 1. Results of investigation.

Parameters				EER [%]
h	*maxdist*	jmp_s	jmp_q	
25	0.1	10	2	4.50
	0.2			5.32
	0.3			4.17
50	0.1			2.00
	0.2			2.01
	0.3			2.02

When analyzing the table 1 it can be noticed that:

- for a bigger window, a reduced EER was obtained.
- In the case of the window *h* = 25, a change in the parameter *maxdist* has a bigger effect on the EER value than in the case of the window *h* = 50.
- Use of the windows method in conjunction with the least square method allowed reducing EER from 6.5% [12] to 2.0%.

5. CONCLUSIONS

The paper presents a method of identification and classification of signatures. It combines the least square method with the windows method. The windows method allows eliminating the necessity of scaling the length of signatures in the comparison process. The studies showed that this approach reduces the error in classification of signatures by a few percent. In the next stage of studies, the influence of all parameters on the effectiveness of the method will be analyzed. Other databases of signatures, containing different types of forgeries, will also be tested.

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