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*IPAN99, characteristic points,
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THE METHOD FOR DETERMINING THE CHARACTERISTIC POINTS OF SIGNATURES BASED ON IPAN99 ALGORITHM

The paper puts forward a new method of determination of signatures' characteristic points. The method is based on seeking points of the highest curvature using the IPAN99 algorithm. The way of IPAN99 algorithm parameters' automatic selection for a particular signature has been fully described. Moreover, the way of determination of additional characteristic points, important for a signatures analysis, has been shown. The presented results of carried out experiments confirm that the proposed method is useful for signature recognition and verification.

1. INTRODUCTION

Biometrics can be defined as the use of behavioural or physiological characteristics to recognize or verify the identity of an individual. Signature is one of the longest known security techniques. Pattern of signature has been for many years an accepted form of credibility determination (e.g. in the case of bank transactions).

Currently a lot of different approaches have been proposed for signature verification in the literature [7,8,9,10]. Their actions are based on the calculation of distance such as Euclidean or Mahalanobis [5,12]. They may also use different models of neural networks or Hidden Markov Models (HMM) [4]. There are also methods based on an analysis of the signatures object characteristics (usually edges or angles points) and reducing the problem to match these points [11].

The maximum size of the signature attributes vector representing the points obtained from a tablet can reach several thousand numbers. Analysing the entire received data string may be too time-consuming taking into the consideration the base of e.g. 10000 signatures. Therefore reduction of the vector size is done. Reduction of data can be achieved by identifying the various important points on contour or some attribute functions of a signature. Usually those are the points representing the curves or corners of signature contour. The main problem is to identify such points, which can keep the shape of the object.

The best-known algorithms seeking the points of highest curvature are: Rosenfeld and Johnston 1973, Rosenfeld and Weszka 1975, Freeman and Davis 1977, Beus and Tiu 1987, IPAN99 [1-3]. In this work an algorithm IPAN99 which has confirmed its high efficiency is used. Unfortunately, its disadvantage is the need for individual selection of parameters for every person.

The article proposes a method for selection of algorithm parameters for each signature in order to obtain the best efficiency.

2. DETECTION OF POINTS WITH THE HIGHEST CURVATURE

Points with the highest curvature play an important role in perceiving the shapes by a human being. In the present thesis, a very fast and efficient algorithm IPAN99 has been applied, which was published in year 1999 [1]. The algorithm IPAN99 defines the corner as a point of a given curve, if we are able to inscribe in that curve a triangle with a given size and angle of the vertical gap.

In the first stage, the algorithm reviews the string of points and selects the candidates for corners. In the second stage, the redundant candidates are eliminated:

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$$\begin{aligned} &d_{\min}^2 \le \left|p - p^+\right|^2 \le d_{\max}^2 \\ &d_{\min}^2 \le \left|p - p^-\right|^2 \le d_{\max}^2, \\ &\alpha \le \alpha_{\max}, \end{aligned} \tag{1}$$

where:

$\left|p - p^+\right| = |a| = a$ – the distance between points p and p^+,

$\left|p - p^-\right| = |b| = b$ – the distance between points p and p^-,

$\alpha \in [-\pi, \pi]$ – the triangle angle of vertical crack defined as follows:

$$\alpha = \arccos \frac{a^2 + b^2 - c^2}{2ab}$$

Values d_{min} and d_{max} are entered into the algorithm as its parameters.

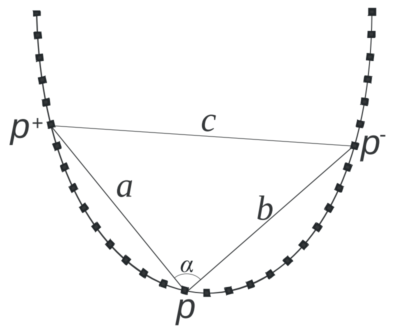

Fig. 1. Detection of points with the highest curvature by means of the IPAN99.

Triangle, which meets the conditions (1) is so-called an acceptable one. The searching for an acceptable triangle is started from the point p on the outside that is from the shortest length of the triangle sides and stops, if any part of the conditions (1) is fulfilled (therefore the restricted number of neighbouring points is taken into consideration). Among all acceptable triangles, the one with the smallest angle of vertical crack is selected $\alpha(p)$. The point p_i belongs to the neighbourhood of p point, if $|p - p_i|^2 \le d^2_{min}$.

IPAN99 algorithm parameters:

d_{min} – the parameter restricting the length of sides from the "bottom". Small values cause that algorithm reacts to small corners.

d_{max} – the parameter restricting the length of sides from the "top". It is necessary to avoid false acute angles created by distant points of the curve

$\alpha_{\max}$ – boundary angle specifying the minimal acuteness, which has to have a point in order to classify it as the candidate for the corner.

The candidate p point is rejected, if it has a shaper neighbour that is p_i point, which is also a candidate, and which was assigned a greater strength of the corner: $\alpha(p) > \alpha(p_i)$.

3. THE METHOD FOR DETERMINING THE CHARACTERISTIC POINTS

The method proposed in the paper for determining the characteristic points of the shape of a signature is based on two elements: an automatic selection of parameters of the IPAN99 algorithm and determination of additional points (so-called boundary points), which are not determined by the IPAN99 algorithm, but they are important for the signature analysis

3.1. AUTOMATIC SELECTION OF PARAMETERS OF THE IPAN99 ALGORITHM

A condition for the correct determination of the high curvature points on the analysed curve with the use of the IPAN99 algorithm is a proper selection of its parameters. Signatures of different persons are characterized by different size and shape. This makes it impossible to determine a single universal set of parameter values of the IPAN99 algorithm for all signatures. This characteristic feature of the algorithm provided the basis for developing a method for automatic selection of a set of parameters of the IPAN99 algorithm. The selection is performed individually for each signature. It is based on the statistical analysis of the values of signature features - in this case: the shape, that is *X* and *Y* coordinates.

Thanks to the use of a tablet, a signature is represented by a set (*P*) of discrete points (*p*) of the signature:

$$P = \{ p_1, p_2, ..., p_n \}, \quad (2)$$

where:

n – a number of signature points.

In order to calculate the statistical metrics, a set *L* containing the distances $l_{i,j}$ between successive points of the signature was determined:

$$L = \{ l_{i,j} \}. \quad (3)$$

The distances $l_{i,j}$ are determined basing on the following formula:

$$l_{i,j} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}, \quad (4)$$

where:

x_i, y_i – coordinates of an *i*-th point p_i of a signature,

x_j, y_j – coordinates of a *j*-th point p_j of a signature.

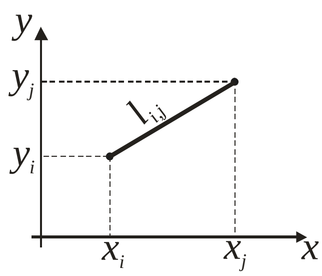

Fig. 2. Graphical representation of the $l_{i,j}$ distance.

On the basis of the set *L* containing values of the distances between points of the signature chart, the mode of the set was determined in accordance with the formula:

$$D = x_0 + \frac{n_0 - n_{-1}}{(n_0 - n_{-1}) + (n_0 - n_{+1})} \cdot c_0, \quad (5)$$

where:

x_0 – the lower boundary of modal class,

n_0 – the frequency of the modal class,

n_{-1} – the frequency of the class preceding modal class,

n_{+1} – the frequency of the class succeeding modal class,

c_0 – the width of the modal class.

3.2. DETERMINATION OF ADDITIONAL CHARACTERISTIC POINTS

In the developed method there are determined two sets of additional characteristic points, which are not determined in the standard IPAN99 algorithm. The first one is a two-element set P_I, which contains the first and last point of the signature registered by the tablet:

$$P_I = \{ p_1, p_n \} , \tag{6}$$

The second set of characteristic points is determined on the basis of the set L. If the distance D_T between two points p_i and p_j is greater than the multiple of the value $d_{\max}$:

$$\begin{array}{l} \left| p_j - p_i \right| > D_T \\ D_T = c_3 \cdot d_{\max} \end{array} , \tag{7}$$

where:
c_3 – multiple coefficient,
both points are considered as additional characteristic points of the signature.

Figure 3 presents charts of the signature with marked characteristic points determined with the use of the IPAN99 algorithm and a chart of the same signature with additional characteristic points.

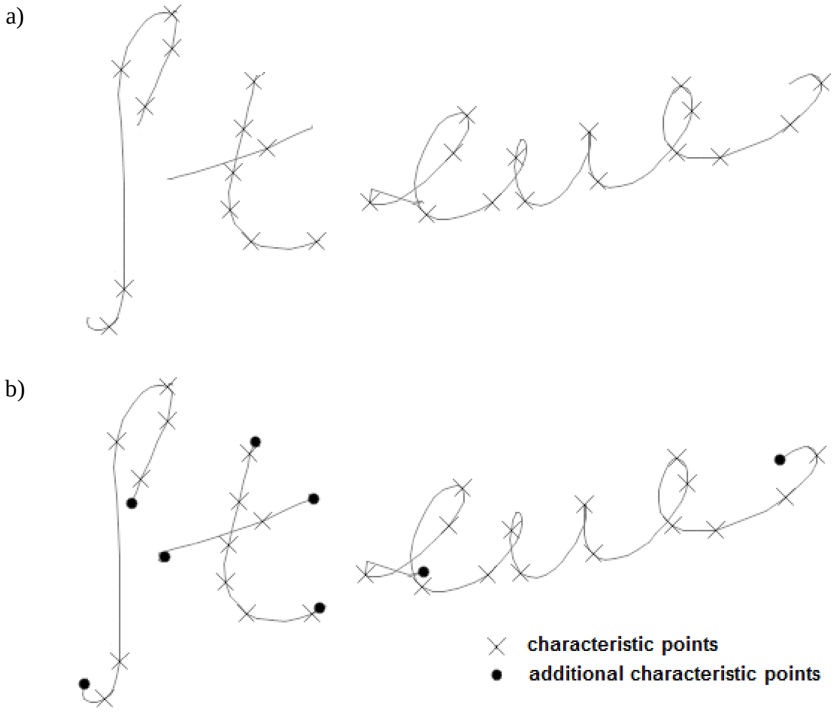

Fig. 3. Signature with marked characteristic points determined
a) without additional characteristic points, b) with additional characteristic points.

Basing on the calculated value of the mode, values of parameters of the IPAN99 algorithm are determined:

$$d_{\min} = c_1 \cdot D , \tag{8}$$

$$d_{\max} = c_2 \cdot D , \tag{9}$$

$$D_T = c_3 \cdot d_{\max} , \tag{10}$$

where:

c_1, c_2 – coefficients multiplying the mode value,

c_3 – coefficient multiplying the d_{max} value.

4. REASERCH

The studies aimed at determining the effectiveness of the signature verification based on a reduced set of signature points. The method of determining the characteristic points described in section 3 was used for reducing the number of points. The set of the analysed signatures contained 96 signatures coming from 16 persons. The signatures were taken from the SVC2004 database (skilled forgeries). Each of the persons put 4 original signatures, while the number of false signatures for each person was 2.

In the course of studies, the following parameters of the algorithm were analysed:

c_1={0.5, 1.0, 2.0}, c_2={2.0, 5.0}, c_3={2.0,5.0}.

The values of the similarity between individual signatures were calculated with the use of the ratio R^2 [6]. For each set of parameters, also the value of EER was determined. Table 1 shows combinations of values of the following parameters: c_1, c_2, c_3, for which the lowest values of EER were obtained.

Table 1. Values of the parameters: c_1, c_2, c_3, for which the lowest values of EER were obtained.

Values of algorithm parameters			**EER [%]**
c_1	c_2	c_3	
1	2	2	4.18
0.5	2	5	4.18
1	2	2	4.18
1	2	2	4.30
1	2	5	4.68
0.5	2	5	4.82

From the conducted studies it appears that the greatest impact on the value of EER has the value of the parameter c_2.

In the next stage of the studies, the average time of comparison of two signatures was determined. The results are presented in Table 2. There was determined the average time of comparison of two signatures with all the points, and the time of comparison of only the characteristic points. Calculations were carried out using Intel Core2 2.4GHz processor with 2GB RAM.

Table 2. The average time of comparison of two signatures.

Comparison on the basis of:	**EER [%]**	**The average time of comparison of two signatures [μs]**
all points	5.01	79
characteristic points	4.18	45

Figure 4 presents the FAR/FRR plots for the best results.

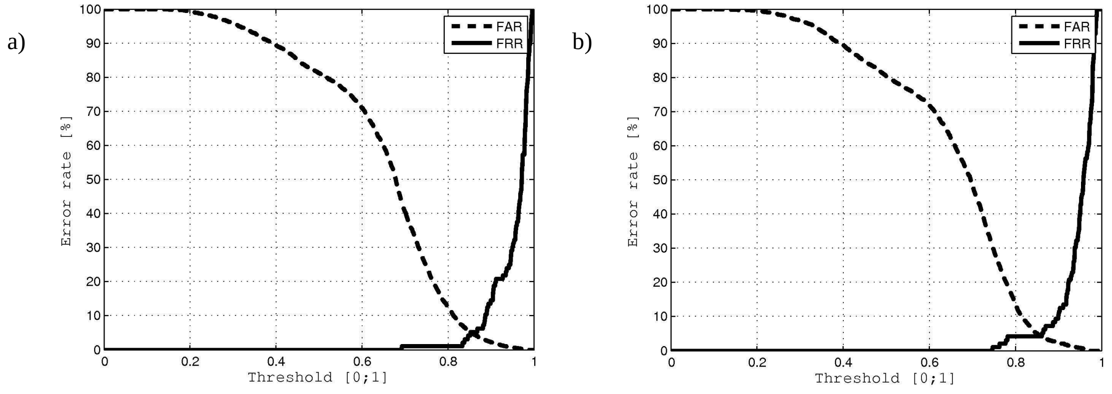

Fig. 4. FAR/FRR plots for the best results: a) for all points, b) for characteristic points.

5. CONCLUSIONS

The studies showed that it was possible to verify signatures basing on an analysis of only the characteristic points determined with the use of the method described in this paper. During the studies, a method of automatic selection of parameters of the IPAN99 algorithm based on statistical analysis of a signature was developed and a set of additional characteristic points was determined.

The method made it possible to achieve an error comparable to the case, in which all points of a signature are analysed. It should be emphasized that the method of comparing only characteristic points of signatures allows speeding up the verification process. The average time of comparing two signatures was reduced from 79 μs during an analysis of all points of a signature to 45 μs when analysing only characteristic points.

The next stage of the studies will aim at determining the usability of other statistical metrics in the proposed method and will broaden the scope of the analysis of the parameters of the algorithm.

Previous studies were conducted taking into account two signature features (coordinates X and Y). In the future, there will be analysed further features of signatures registered with the use of a tablet, such as the pen pressure on the tablet and speed of the pen in individual points of a signature.

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