*signature recognition,
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COMBINED OFF–LINE TYPE SIGNATURE RECOGNITION METHOD

In this paper the off–line type signature analysis have been presented. The signature recognition is composed of some features. Different influences of such features were tested and stated. Proposed approach gives good signature recognition level, hence described method can be used in many areas, for example in biometric authentication, as biometric computer protection or as method of the analysis of person's behaviour changes.

1. INTRODUCTION

The signature recognition is the process of writer's verifying by means of the samples signature that are comparing with stored in the database records. The result of this process is usually a number between 0 and 1, which represents a matching ratio. The signature recognition is one of many biometric identification techniques, which are used in practice. In the business world we sign things such as accounts and other official documents. Our personal signature lends itself well for biometric verification in state–of–the–art electronic commerce. Unfortunately, one drawback of signature is that people do not always sign documents in exactly the same manner. For example, the angle at which they sign may be different due to seating position or due to hand placement on the writing surface. For this reason, the original signature should be appropriate formatted and pre-processed. In our approach, the signature analysis process is composed of three main stages:

Pre–processing: where image standardisation procedures are performed,

- feature extraction: where the unique set of characteristics of the analysed signature is gathered,
- comparison: where personal signature is compared with the pattern from the database.

Above mentioned important stages will be described in the next part of the paper.

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2. PRE–PROCESSING

The pre–processing procedure consists of three steps:

– binarization: which allows us to reduce the amount of image information (removing colour and background), so the output image is black-white. That type of the image is easier to further processing (Fig.1b).

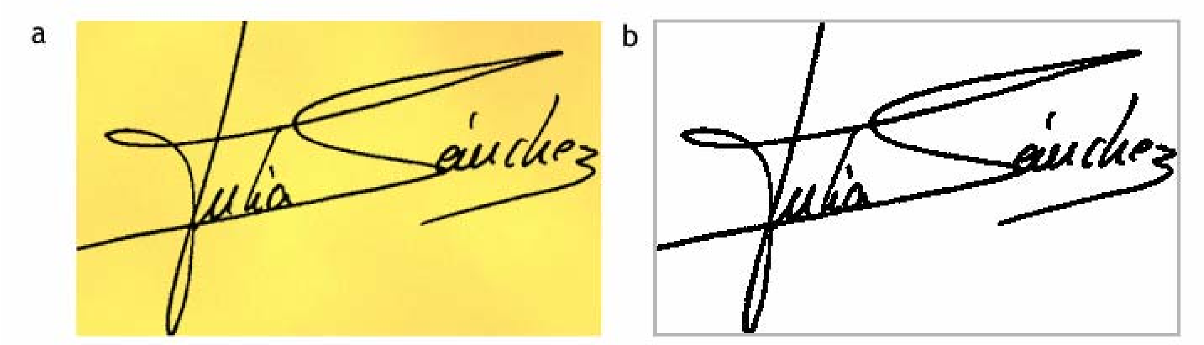

Fig. 1 Binarization process: a) personal signature image, b) signature after binarization

– cutting edges: where size of the image is reduced. In this procedure unnecessary signature areas are removed. In other words, the image is cut to the signature size. It allows reducing the total number of the pixels in the analysed image (Fig.2),

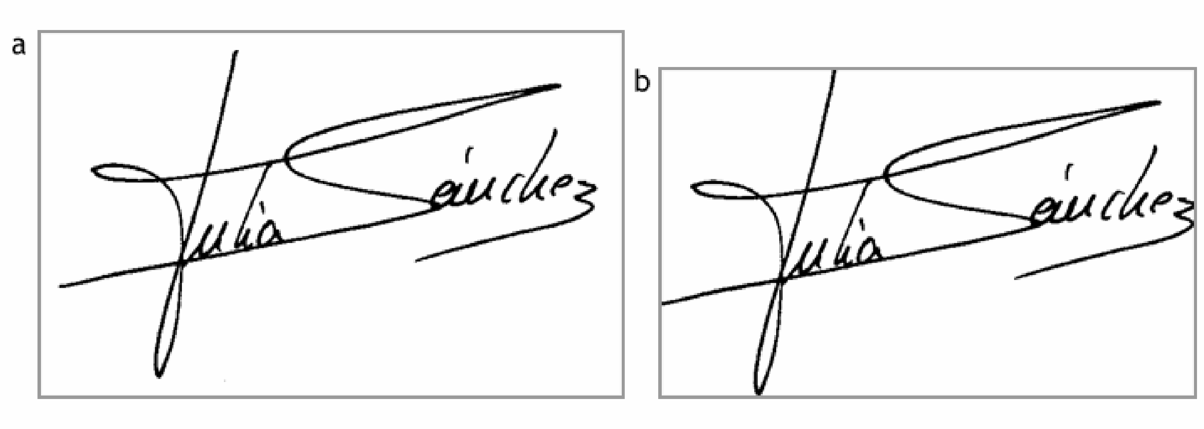

Fig. 2 Reducing of the image size: a) binarized personal signature, b) reduced image

– thinning: allows us to form a region-based shape of the signature. It should be noticed that main features of the object are protected. After thinning, the 1-pixel shape of signature is obtained (Fig.3) [1].

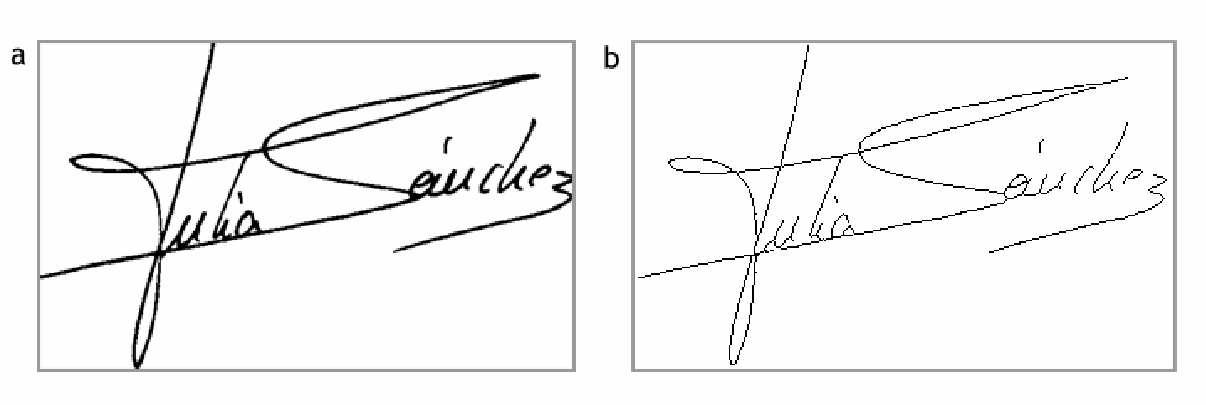

Fig.3 Image thinning: a) raw signature; b) thinned image

3. FEATURE EXTRACTION

During that step a gathering of characteristic data takes place. The output result is a set of the unique information about the signature. Actions occurring during that step supply:

- ratio coefficient: it defines the relation between width and height of the different personal signatures which are signed by the same person,
- vertical and horizontal projection: this projection describes the vertical and horizontal pixels density of the signature (histogram). After the data collecting, projections are calibrated to resolution of 256×256 pixels. Applying the calibration allows to compare the projection with different size signatures,
- centre of gravity: it supplies information about the layout of pixels' density. It is a point where two lines (vertical and horizontal) are crossing. These lines divide the signature image into vertical and horizontal regions where number of pixels is the same.

In the next stage, after the three previous steps, which are quite easy to perform, the Hough transformation (HT) is used with some optimizing algorithm. That part of the algorithm produces a set of the line segments that are characteristics of the signature.

In our approach the Hough transformation consist of the next steps:

- In the first step the standard Hough transformation is applied (Fig.4). The classical transformation identifies lines in the image (signature), but it has been extended to identifying positions of arbitrary shapes. The results of this transformation are stored in a matrix that is known as accumulator array [2]. This transformation is well known in the research community, therefore its details will be ommited.
- In the second step finding of the local maxima is introduced. The maxima values are searched in the accumulator array. The analysed signature consists of lines, which were found by Hough transform, hence this stage allows to reduce the number of such lines. The range of the line reduction by experiments was investigated, where thresholding procedure was applied (Fig.5).

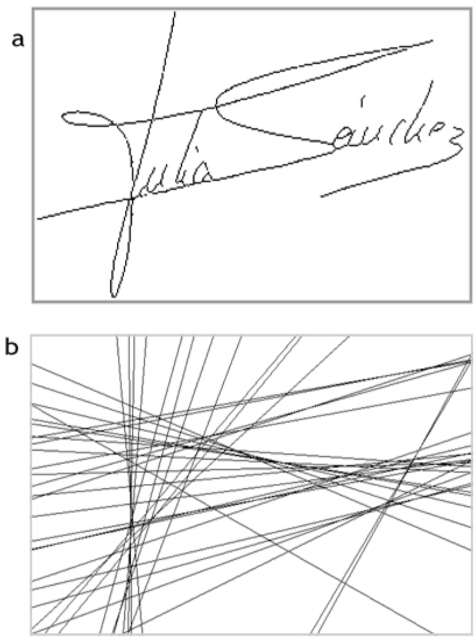

Fig. 4 The Hough transformation: a) thinned signature, b) extracted features after simple HT

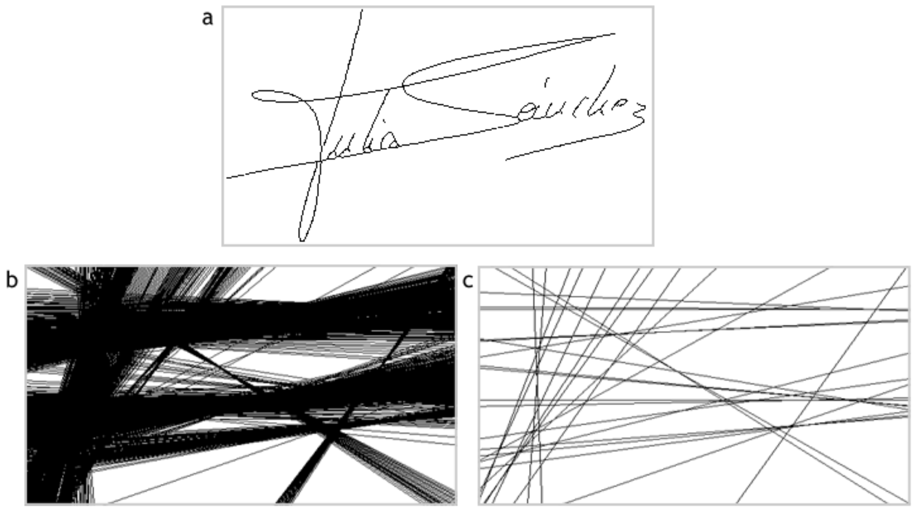

Fig. 5 Local maxima finding: a) analyzed signature, b) extracted straight lines after HT, c) the reduced number of the lines obtained from the thresholding procedure

- Straight–line selection algorithm: it similar lines have been found, then such lines are joined each other (Fig.6).
- The outline parameterization – the output result is a set of information (coordinates) about the line segments lying along on the same line (Fig. 7).

Fig. 6 Straight–line selection algorithm: a) signature, b) the set of the signature lines, c) grouped and reduced lines

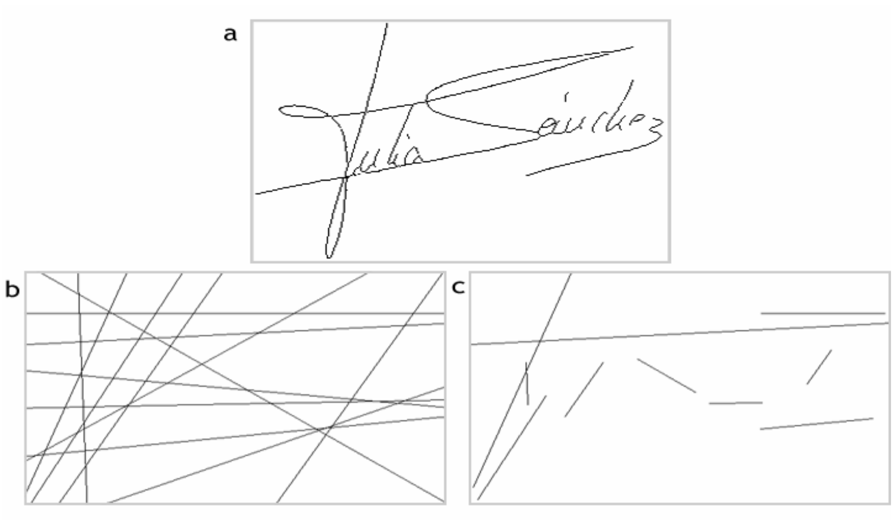

Fig. 7 The outline parameterization: a) pre-processed signature, b) the reduced set of the signature lines, c) lines allocated to appropriate segments

– Connecting lines – this algorithm connects the line segments lying along on the same line, where distance between such segments is lower than defined coefficient (Fig. 8).

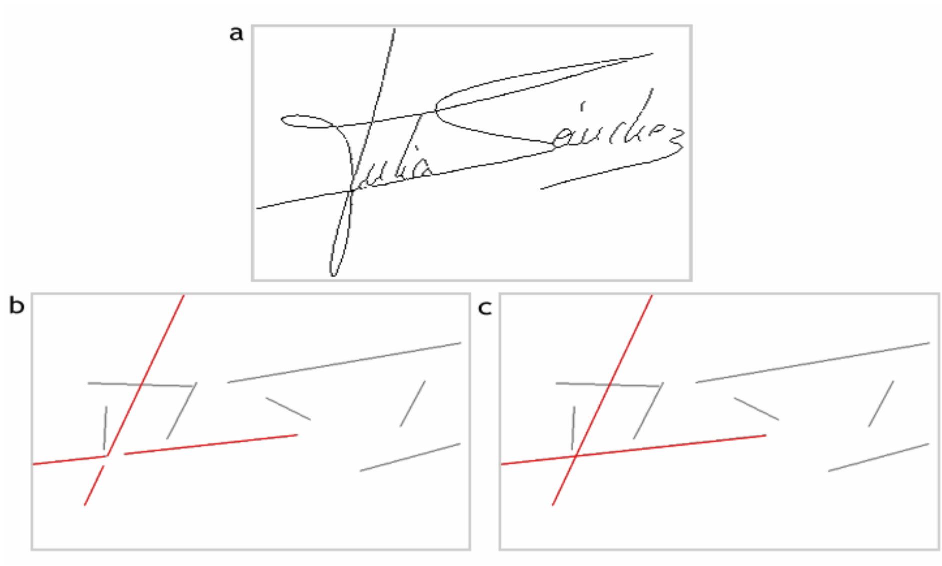

Fig. 8 Principle of the line segments connecting: a) input signature b) line segments c) joined segments

- The size calibration: the set of line segments is calibrated to 256x256 pixel-size image. It allows to compare signatures which originate from different sources and have different sizes (Fig.9)

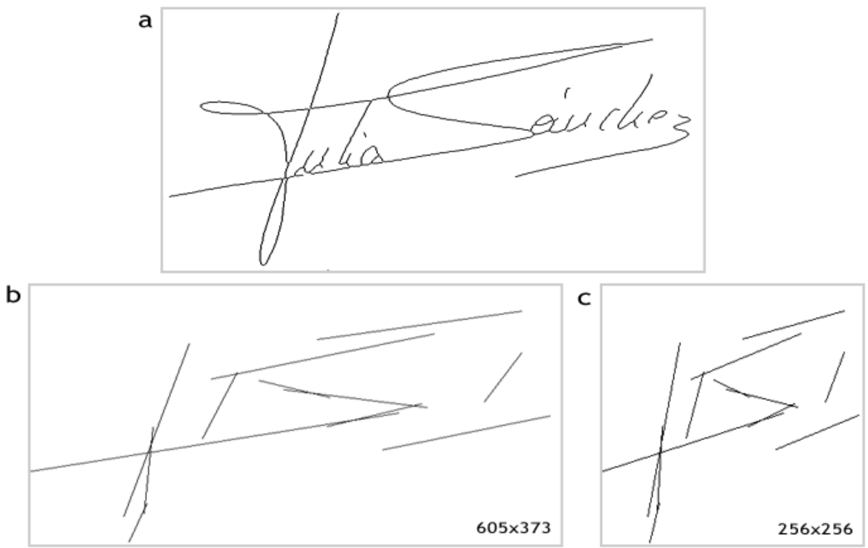

Fig. 9 The size calibration: a) input signature, b) initial size, c) normalized size

The set of the line segments is the most unique feature, which describes the signature. It will be shown in the conclusive investigations.

4. DEREMINING OF THE PATTERN SIGNATURE

For recognition process, the input and genuine signatures should be known. In this process, the unique features (patterns) of each signature are compared with analysed input sign. For this reason, the patterns of the genuine signature are stored in a database. These patterns would contain all characteristic features of signature (the set of line segments, projection coefficients, coordinates of the centre of gravity). Unfortunately, signatures of the same person have some differences. So it is needed to build a pattern, which cover these differences.

In proposed approach was implement a procedure that determines similarity between signatures. The input data in this procedure are two sets of unique features that are received from two signatures. As the output data it returns a global similarity coefficient s. Separately are also determined similarity coefficients for each of the four features s_s, s_p, s_r and s_g. Finally, the global similarity coefficient is calculated by using the following formula:

$$s = s_s p_s + s_p p_p + s_r p_r + s_g p_g \tag{1}$$

where :
s_s – line segments similarity coefficient,
s_p – projection similarity coefficient,
s_r – proportion similarity coefficient,
s_g – centre of gravity similarity coefficient.

Above mentioned coefficients are formed by comparing each feature from one set with corresponding feature from the another set. Finally, the appropriate similarity coefficients are calculated.

For every s–type coefficient appropriate p–type (p_s, p_p, p_r ,p_g) weights are selected and additionally, the condition $p_s + p_p + p_r + p_g = 1$ have to be fulfilled.

When the similarities procedure is already implemented, it is possible to build a signature patterns. The patterns are determined on the basis of a few (say three) signatures of the same persons. Such signatures should be collected at different day-time, during the whole week. In the next stage, features of the three signatures are compared each other. As the pattern is chosen this signature that has the highest global similarity ratio (i.e. that is the most similar to others signature) and that pattern, and its characteristic features, is stored in database. Using that pattern will be performed for all future comparisons.

5. SIGNATURE VERIFICATION AND IDENTIFICATION

There are two areas of application for signature recognition systems:

Verification – where the input signature (and its characteristic features) is comparing with only one pattern from the database and judging if these signatures are the same or not.

Identification – where the corresponding pattern in database is searching until the one matches the input signature.

Both methods mentioned above use global similarity coefficient and global threshold value. The verification and identification are successful if the similarity for a tested signature is at least equal to global threshold value.

The global threshold value bases on the formula:

$$t_{\psi} = (1-\psi)(t_s p_s + t_p p_p + t_r p_r + t_g p_g), \qquad (2)$$

where:

t_s, t_p, t_r, t_g – partial thresholds for the elements of the pattern (set of segments, projection, ratio coefficient, centre of gravity)

p_s, p_p, p_r, p_g – importance (weight) for each feature (set of segments, projection, ratio coefficient, centre of gravity)

ψ – tolerance coefficient

Tolerance coefficient has some considerable influence on the final result of verification and identification. It reduces the partial thresholds (so the global threshold as well) of the given percentage.

6. INVESTIGATION RESULTS

In the investigations, characteristic features (set of segments, projection, ratio coefficient, centre of gravity) have been tested separately, and the influence of the each feature has been observed. The test gave information about changes coefficients FAR (false accept rate) and FRR (false reject rate), depending on participation of the characteristic feature (steps from 0% to 100% every 5%; where 0% means test without feature and 100% means the test with one feature only).

Below there is a summary of investigation results, according to each feature:

- The set of line segments. The investigations proved that this feature is the most important of all other features and the best results were achieved when the participation of that feature (in all features) was above 50%. The FAR coefficient was almost the same during whole test, but the FRR coefficient decreased.
- Projection. Carried out investigations shown that the participation of that feature should be a half of the line–segments coefficient (the best result was obtained for level 32%). FAR was decreasing very clearly and FRR was just quite opposite (and when the proportion was 100%, FRR reached value 20%).
- Proportion coefficient. The test showed that this similarity coefficient is the less important feature (the best results were achieved when the coefficient was very low: about 2%). When FAR decreased, FRR rapidly grown.
- Centre of gravity. The influence of such similarity coefficient is quite similar to proportion coefficient – the best result is about 12%.

Based on the results above, the influence for each feature has been implemented into application (Fig. 10).

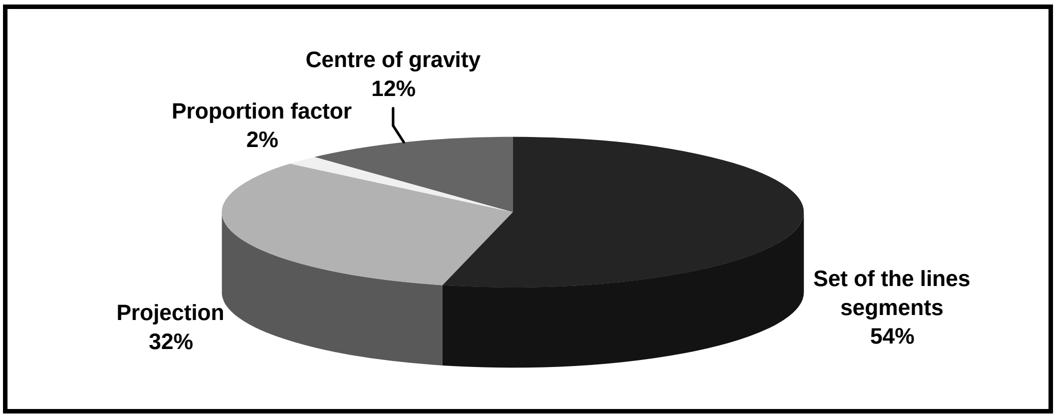

Fig. 10 The best participation of the signature similarity features

The systems worked with very good FAR ratio (0.1 %), but the FRR ratio was not impressive: its level has 18% only. So it was needed to establish tolerance of threshold acceptance.

Searching the tolerance of threshold acceptance was quite similar to previous investigations: the whole range (0%–100%) of tolerance was investigated (with step: 5%). The obtained result shown that the best tolerance level is 16%. FRR falls down considerably and FAR clearly increased.

Experiments are carried out to estimate the performance of utilizing proposed approach in a combined matching system. Obtained results have been shown in Table 1.

Table 1. Comparison of the two modes of the signature recognition

Identification (%)			Verification (%)		
FAR	FRR	Effectiveness	FAR	FRR	Effectiveness
1,79	3,57	94,60	3,94	5,36	96,00

The investigations were carried out for collected 1000 signatures stored as bitmaps. About 800 signatures were collected in our own database. Each signature contributed four signatures (2 signatures × 2 session with an interval of two weeks).

7. CONCLUSIONS

A fundamental problem in the field of off-line signature verification is the lack of a pertinent shape factor. The main difficulty in the definition of pertinent features lies in the local variability of the signature line, which is closely related to the intrinsic characteristic of human beings. In this paper a new combined method of signature analysis have been proposed, where extraction signature line–segments, its proportion, horizontal and vertical histograms and centre of gravity have been stated. Experimental evaluation of this scheme has been made using a signature database of 800 genuine signatures. Experiment carried out confirmed that proposed method is efficient and its effectiveness level is very attractive.

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