Interoperability of Biometric Systems: Analysis of Geometric Characteristics of Handwritten Signatures

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Abstract. Handwritten signatures are considered one of the most useful biometric traits for personal verification. In the networked society, in which a multitude of different devices can be used for signature acquisition, specific research is still needed to determine the extent to which features of an input signature depend on the characteristics of the signature apposition process.

In this paper an experimental investigation was carried out on constrained signatures, which were acquired using writing boxes having different area and shape, and the different behaviour of geometric features with respect to the writing boxes is discussed.

1 Introduction

Handwritten signature is one of the most common biometric traits for personal authentication. A signature is a rapid movement that has been defined, learned and practiced over the youth years, in literate populations, to become a very personal pattern. Therefore, it originates from a complex process that involves the human brain to process information to perform with the human writing system (based on hand, arm, etc.), using writing acquisition equipment (pen, pencil, paper, etc.). Therefore, it is not surprising that - in recent years - many efforts have been devoted to automatic signature verification, attracting researchers from different fields. More precisely, so far research efforts have been mainly devoted to determine effective features and comparison strategies for signature verification [1].

Concerning features, both functions and parameters were considered in the literature. When function-features are used, the signature is characterized by a time-function, whose values constitute the feature set. Among others, widely used functions features are position, velocity, acceleration and pressure. When parameter-features are used, a signature is characterized as a vector of parameters, each one representative of the value of a feature. Among others, widely considered parameters are total signature time duration, pen-down time ratio, number of pen-lifts, direction- and curvature-based features.

When comparison strategies are considered, both distance-based and model-based approaches have been widely investigated in the literature. Concerning distance-based verification techniques, Mahalanobis and Euclidean distances have been used for signature comparison as well as Dynamic Time Warping (DTW) and string matching

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strategies. When model-based techniques are considered, Hidden Markov Models (HMM) have found to be well-suited for signature modelling since they are highly adaptable to personal variability and lead to results that are – in general - superior to other signature modelling techniques [2].

Notwithstanding several relevant results have been achieved so far, many aspects still remains to be investigated, in order to make signature verification feasible in a multitude of daily operations. Among the others, one of the most relevant open aspects concerns the relation between the constraints during the signature apposition process and the characteristics of the input signature. In fact, signers can use different devices (tablet, smartphone, PDA, etc.) to input their signatures and hence the verification system must be aware of the differences in the input signatures due to the acquisition conditions [3].

In this paper we perform an experimental investigation on signatures acquired under constrained conditions. More precisely, the relations between some geometric features of the input signature and size and shape of the writing area are analysed. The experimental results demonstrate that, in general, area is highly dependent on the writing area, whereas ascendants and descendants are low dependent on the writing area.

The organization of the paper is the following. Section 2 presents the experimental setup. Section 3 reports the experimental results. Section 4 addresses the conclusion of the paper and some considerations for future work.

2 Experimental Setup

The experimental setup was realized using a Wacom Intuos tablet and an Intuos Grip Pen. The Intuos Grip Pen is a cordless, battery-free and pressure-sensitive freehand writing device. Macros on the Wacom Intuos tablet ensure that the area of signature was positioned in the centre of the tablet in order to maximize comfort and sensitivity of the user. Four conditions have been considered to represent some common area and shape constraints in signature apposition:

a) Constraint 1: 4.6cm x 0.77cm rectangular box (to analyse the effect of constriction in small boxes);
b) Constraint 2: 7.0cm x 1.5cm rectangular box (space-like signatures of the identity card and bank checks);
c) Constraint 3: 14cm x 1.5cm rectangular box;
d) Constraint 4: 12cm x 7cm rectangular box (to see the biggest change of signature);

Figure 1 shows the five types of constraints that have been considered for signature apposition in this paper:

During the enrolment stage 10 signers have been involved in data acquisition. For each type of constraint, six signatures were captured from each signer. Therefore, each signer collected a total number of 6x4 = 24 genuine signatures. During testing the signer sat down and wrote comfortably to increase comfort and truthfulness.

Fig. 1a. Rectangular box (4.6cm x 0.77cm)

Fig. 1b. Rectangular box (7.0cm x 1.50cm)

Fig. 1c. Rectangular box (14.0cm x 1.50cm)

Fig. 1d. Rectangular box (12.0cm x 7.0cm)

The following figures (2a – 2l) show some examples of signatures acquisition. More precisely, they show the acquisition of signatures of three users (user 1, 2 and 3) with respect to the different types of signature constraints.

Fig. 2a. User 1 – 4.6 x 0.77

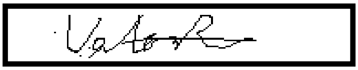

Fig. 2b. User 2 – 4.6 x 0.77

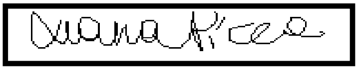

Fig. 2c. User 3 – 4.6 x 0.77

Fig. 2d. User 1 – 7 x 1.5

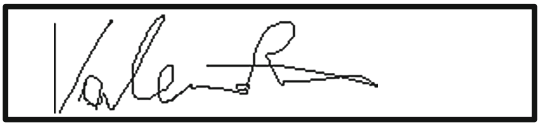

Fig. 2e. User 2 – 7 x 1.5

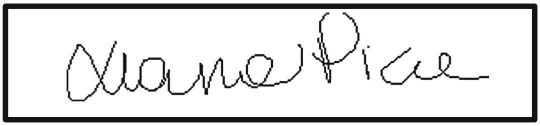

Fig. 2f. User 3 – 7 x 1.5

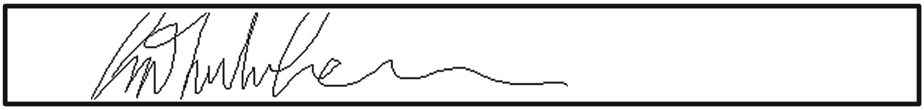

Fig. 2g. User 1 – 14 x 1.5

Fig. 2h. User 2 – 14 x 1.5

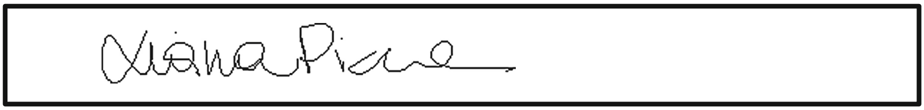

Fig. 2i. User 3 – 14 x 1.5

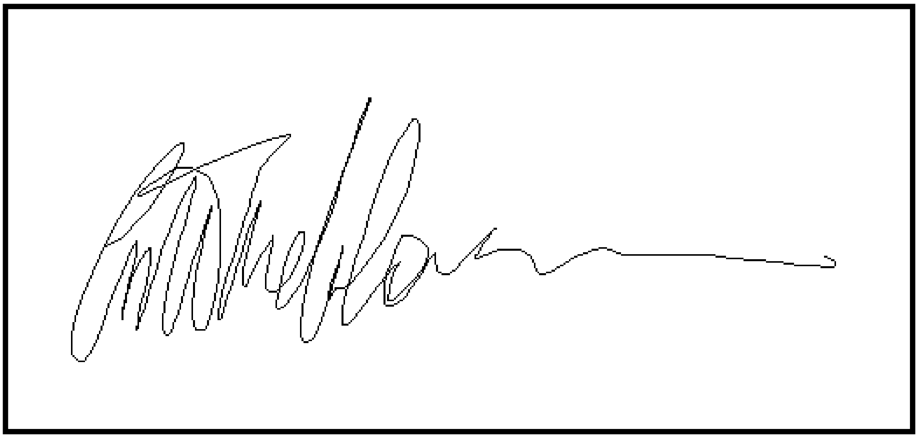

Fig. 2j. User 1 – 12 x 7

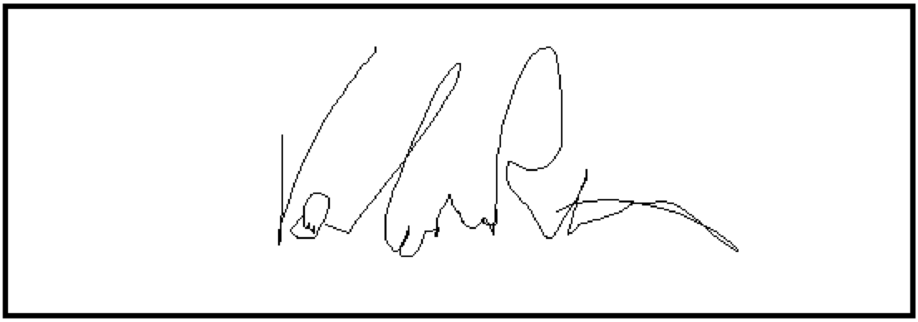

Fig. 2k. User 2 – 12 x 7

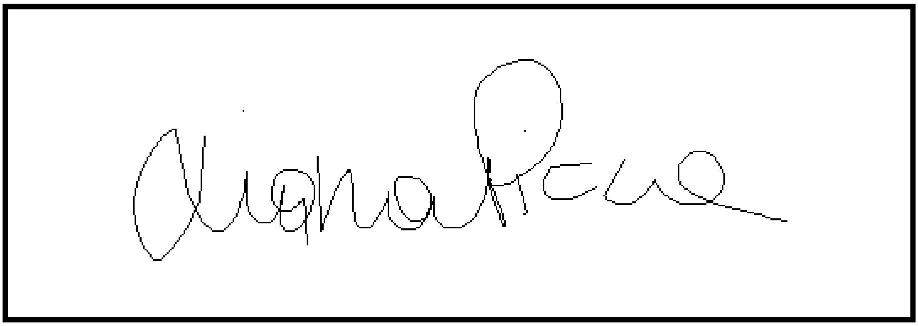

Fig. 2l. User 3 – 12 x 7

3 Experimental Results

A specific software system was developed in Java for the analysis of the experimental data. The signature image is the input of the system, the output is the values of some geometrical characteristics extracted from the signature:

- F_1: Signature Area (A_s)
- F_2: Signature Height (H_s)
- F_3: Signature Width (W_s)
- F_4: Ascendants of signature (H_a)
- F_5: Descendants of signature (H_d).

More precisely, concerning F_1, F_2 and F_3, let be:

- H_s = Height of signature;
- W_s = Width of signature;
- H_i = Height of the space of signature;
- W_i = Width of the space of signature;
- $A_s = H_s * W_s$;

they are defined as follows (see Figure 3a):

- $F_1 = A_s/(H_i * Wi)$;
- $F_2 = H_s/H_i$;
- $F_3 = W_s/W_i$.

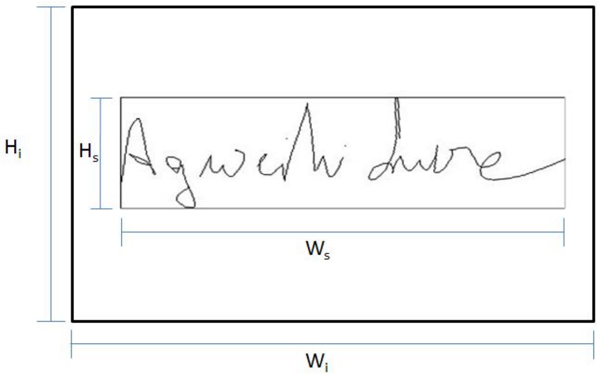

Fig. 3a. Area, height and width determination

Concerning F_4 and F_5, they are defined as follows (see Figure 3b):

- $F_4 = H_a/H_i$;
- $F_5 = H_d/H_i$.

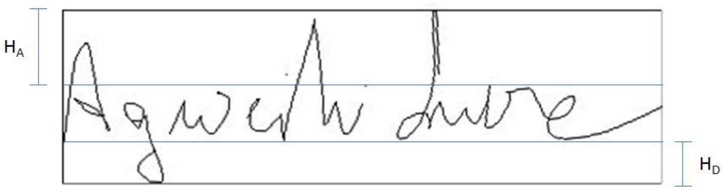

Fig. 3b. calculation of ascendants and descendants of signature

For each signer the analysis of variance (ANOVA) among pairs of groups of constrained signatures was performed [4]. ANOVA starts from the assumption that for G groups of data, it is possible to decompose the variance into two components: the variance inside the groups and the variance between groups. From these values, calculated as the sums of the standard deviations between the groups and within a single group, we can get a test variable for comparison with the value of a variable Fisher "F", taking into account the degrees of freedom, according to the significance level α to evaluate the results.

Table 2 reports, for each geometric feature, the results of dependence in relation to different pairs of constraints considered, obtained on the entire sample considered for the analysis. The values shown in the table are obtained on the basis of the results of the ANOVA for each subject (with $\alpha = 0.05$), for which the value 1 indicates dependence, while the value 0 indicates not dependence of the characteristic in relation to the pair of restrictions chosen.

Then, let be:

- N : number of users (N=10 in our tests);
- F_j : j-th features considered ($1 \le j \le 5$)
- C_k : k-th the couple of constraints considered, where
  - k=1 means the couple of constraints 1 and 2
  - k=2 means the couple of constraints 1 and 3
  - k=3 means the couple of constraints 1 and 4
  - k=4 means the couple of constraints 2 and 3
  - k=5 means the couple of constraints 2 and 4
  - k=6 means the couple of constraints 3 and 4.
- $V_{ijk} \in \{0, 1\}$: dependence/not dependence value (based on the ANOVA test) for the i-th subject, based on the j-th feature and the k-th couple of restrictions.

The value of each item in Table 2 is calculated by averaging the values V_{ijk} with respect to the number of users:

$$\mathrm{Xjk} = \frac{1}{N}\sum_{i=1}^{N} Vijk \ .$$

Table 2 demonstrates that the signature area (F_1) is the characteristic most dependent on the different constraints imposed on the space of signature. Height (F_2) and width (F_3) of signature show values that oscillate, in relation to the pair of restrictions considered. Ascendants (F_4) and descendants (F_5) of signature are the characteristics that do not seem to be affected by various restrictions imposed on the area of signature.

Table 1. Dependence of the characteristics related to couples of restrictions.

Feature\Constraint	1 – 2	1 – 3	1 – 4	2 – 3	2 – 4	3 – 4
F_1	0,5	1	1	0,9	1	0,9
F_2	0,6	0,5	1	0,3	1	1
F_3	0,2	0,9	0,6	1	0,5	0,9
F_4	0,5	0,3	0,4	0,2	0,4	0
F_5	0,1	0	0,5	0,1	0,3	0,2

4 Conclusion and Future Work

An experimental investigation on the effects of the characteristics of the writing area on the geometric features of online signatures is addressed in this paper. For the purpose four different signature acquisition areas were considered (which differ in terms of area and shape) for signature acquisition and the ANOVA test was applied to verify to what extent geometric features of a signature depends on the writing area. The experimental results demonstrate that area of signature seems to be very dependent on the writing area, whereas ascendants and descendants of signature does not seem to be influenced by different constraints.

Although this study is not sufficient to derive general assumptions on the characteristics of constrained online signatures, it poses new interesting problems to the scientific community both for improving the knowledge on human behaviour in signing and for improving future systems for automatic signature verification. Among the others, an interesting aspect for assuring interoperability of signature verification systems could be the possibility to develop new (signer-dependent or signer-not dependent) techniques for normalization of constrained signatures.

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