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Characteristics of Constrained Handwritten Signatures: An Experimental Investigation

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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 dynamic features with respect to the writing boxes are discussed.

1. Introduction

Handwritten signature is one of the most common biometric traits for personal authentication. A signature is a rapid movement that is defined, learned and practiced over the youth years to become a person's peculiar identifying pattern. 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 (Impedovo and Pirlo, 2008).

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 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 (Plamondon et al. 2014).

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 (Simsons, 2011).

In this paper we perform an experimental investigation on signatures acquired under constrained conditions. More precisely, the relations between some dynamic features of the input signature and size and shape of the writing area are analysed. The experimental results demonstrate that, in general, velocity is highly dependent on the writing area, whereas acceleration is 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 Intuos3 tablet and an Intuos3 Grip Pen. The Intuos3 Grip Pen is a cordless, battery-free and pressure-sensitive freehand writing device [5]. Macros on the Wacom Intuos3 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. Five conditions were considered to represent some common area and shape constraints in signature apposition:

- a) 4.6cm x 0.77cm rectangular box (to analyse the effect of constriction in small boxes);
- b) 7.0cm x 1.5cm rectangular box (space-like signatures of the identity card and bank checks);
- c) 14cm x 2cm rectangular box
- d) 12cm x 7cm rectangular box (to see the biggest change of signature);
- e) 12cm guideline (that is present for signature apposition on several administrative forms)

Figure 1 shows the five types of constraints that were considered for signature apposition in this paper. During the enrolment stage, 15 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 $6 \times 5 = 30$ genuine signatures. During testing the signer sat down and wrote comfortably, with a sheet of paper placed on the tablet to increase comfort and truthfulness.



Figure. 1a: rectangular box (4.6cm x 0.77cm)



Figure. 1b: rectangular box (7.0cm x 1.50cm)



Figure. 1c: rectangular box (14.0cm x 1.50cm)



Figure. 1d: rectangular box (12.0cm x 7.0cm)



Figure. 1e: guideline (12.0cm)

Before the acquisition process, each participant filled an anonymous questionnaire concerning personal information: age, sex, education level, writing mode (right or left hand). The results, reported in Table 1, showed the homogeneity of participants, with a slight predominance of males, mostly included in the group of 20-40 years old subjects. Almost all of the subjects were right handed.

Table 1. Database: Characteristics of the Signers

Characteristic	Feature	Percentage
Sex	Male	60%
	Female	40%
Age	16 – 20 years old	26%
	20 – 40 years old	60%
	More than 40 years old	14%
Education Level	5 years (elementary school level)	6%
	8 years education	20%
	13 years education	40%
	More than 16 years (University Level)	34%
Writing Mode	Right - Hand	94%
	Left - Hand	6%

3. Experimental Results

For the analysis of the experimental data, the MovAlyzeR suite was used. The suite contains ScriptAlyzeR™ that can transform a tablet, a mouse or a pen in a high quality system for the measurement of hand-based writing movements. Using MovAlyzeR the experiment was divided in three sub-phases: "Groups", with reference to the number of the test, "Subject", that concerns the identification number (ID) of each one of the fifteen participants, and "Constraints", that concerns the identification code (IC) of each one of the five writing constraints (see Figure 1).

The data collected through MovAlyzeR were analysed in order to determine statistical differences in the following dynamic features:

- Velocity in the vertical direction (V_y)
- Velocity in the horizontal direction (V_x)
- Acceleration in the vertical direction (A_y)
- Acceleration in the horizontal direction (A_x)
- Pressure in the vertical direction (P_y)
- Pressure in the horizontal direction (P_x).

For each signer the analysis of variance among the five groups of constrained signatures was performed. For the purpose the ANOVA test was considered (Gelman, 2005). 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 signer and each dynamic feature, the results of the ANOVA test (with $\alpha = 0.05$ in our tests), where: "D" – Dependent; "ND" – Not Dependent. Velocity seems to be the feature that mostly depends on the size/shape constraints of the writing area. All users have changed the writing velocity to adapt the signing process to the writing space. In general we observed low velocity in small boxes and high velocity in large boxes. The analysis of pressure and acceleration, instead, demonstrate no general behaviour of signers. For these two characteristics, it seems the behaviour of signers not to change significantly due to constraint of the writing area.

Table 2. Dependence of Dynamic Features from Constraints in Signature Acquisition

User	Vy	Vx	Ay	Ax	Py	Px
1	D	D	ND	ND	ND	ND
2	D	D	ND	D	ND	D
3	D	D	ND	D	ND	D
4	D	ND	ND	ND	D	D
5	D	D	ND	ND	ND	ND
6	D	D	ND	ND	D	ND
7	D	D	ND	ND	ND	ND
8	D	D	ND	ND	D	ND
9	D	D	ND	D	ND	ND
10	D	D	ND	D	ND	ND
11	D	D	ND	ND	ND	D
12	D	D	ND	D	ND	ND
13	D	ND	ND	ND	D	D
14	D	D	ND	ND	ND	ND
15	D	D	ND	ND	ND	D

4. Conclusion and Future Work

This paper presents an experimental investigation on the effects of the characteristics of the writing area on the dynamic features of online signatures. For the purpose five different signature acquisition areas were considered (which differ in terms of area and shape) for signature acquisition and the ANOVA test were applied to verify to what extent dynamic features of a signature are depends on the writing area. The experimental results demonstrate that velocity seems to be very dependent on the writing area whereas acceleration and pressure behaviour depends on the specific signer.

Although this study is not sufficient to derive general assumption 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 dynamic features normalization for constrained signature.

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