FORENSIC HANDWRITING ANALYSIS: A RESEARCH BY MEANS OF DIGITAL BIOMETRICAL SIGNATURE

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FORENSIC HANDWRITING ANALYSIS: A RESEARCH BY MEANS OF DIGITAL BIOMETRICAL SIGNATURE

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Abstract: Forensic handwriting examination has a new frontier: the digital signature in biometric modality that uses, for recognition purposes, the anatomic and behavioural characteristics that an individual exhibit when signing her/his name. Data such as the dynamically captured direction, stroke, distance, size, pressure and shape of an individual's signature enable handwriting to be a reliable indicator of an indivudul's identity. "Namirial" is an Italian company that created a biometric signature system named "GrafoCerta" (sure signature) that has a forensic sector particularly suitable for research. A team of experts – computer engineers and handwriting experts- collaborate in the project and created a research laboratory on handwriting. In this paper i will expose the study we made on the correlation between pressure and speed.
Keywords: Authentication, digital signature, biometrics, public key in-frastructure.

Introduction

Handwriting Examiners often has to determine if the signature is genuine or simulated, dynamic information such as velocity and pressure are fundamental and can be estimated qualitatively.
In recent years a technological revolution has affected the world of writing. Most companies today need to have lower costs for archiving and transmission of document and in the same time it was posed the security question. The answer has been the digital biometric signature: Biometrics is actually the science of using digital technologies to identify a human being based on the individual's unique measurable biological characteristic. Applied to handwriting, biometrics enable the comparison between digital signatures in order to avoid falsification and disclaimer. This is a new challenge in forensic examinations because time are not yet ready for experts: more and more often we are called to compare on-line/biometric signature with on-paper ones or two (or more) signatures taken with different software and instruments.
On-paper analysis and biometrics are completely different systems: the first is based on interpretation methods shared by the scientific community, sometimes not sufficiently reliable, that requires great professionalism with the risk of subjectivity in the conclusions; the other is based on mathematic data that not always is able to convert and describe the real handwriting dynamic because the mathematic model has the main disadvantage to be based on specific measurements which may lead to a loss of information on complexity.
The value of pen pressure as a discriminatory feature has been described in several of the texts on Document Examination (Osborn, 1920, Huber & Headrick, 1999, Lindblom & Seaman-Kelly, 2006). Tytell (1998), concluding that "dynamic pressure patterns are an integral part of an individual's signature" and "the pressure patterns of

a well-developed signature of normal length are extremely difficult, if not impossible, to duplicate when imitating another's writing, especially when attempting to reproduce details of formation and method of production." Schomaker & Plamondon (1990) commented that "in signature verification, the force exerted by the pen on the paper during handwriting appears to be a discriminating parameter between individual writers."

Estabrooks concluded that "generally speaking, the overall pressure patterns of a writer's signature have been shown to be habitual and individualistic to that writer."

This study examined genuine signatures from a dynamic point of view, to determine if there is any significant difference in pen pressure between original signature written at different speed.

This is because the handwriting motor memory is constituted by procedural memory components which permit to perform the stroke sequences relative to graphic gesture required. Feedback loops process and control, step by step, motor gesture while executing.

In replication, the motor program must be adapted to each concrete execution condition: in the case of spontaneous writing feedback loops play a marginal role, subsequent letters of writing pattern are prepared in advance while executing the firsts and processing feedback from previous letters: handwriting is performed as fast as 200-400ms. Pushing the motor system to hard limits, forcing normal adaptation parameters, variations on dependent variable appear.

The reliability of the examination process, in handwriting expertise, rides on the ability of the expert to get the subjective dynamic of a graphic style ant to be able to explain the writing movement complexity with objective data. The intricacy of movement patterns and its relation to the perceived complexity is not yet well-defined in forensic literature.

Using the "Namirial" software, we convert the graphic trace in numbers and in percentage reports that we elaborate to draw conclusions about graphical laws usually used in expertise. Our goal is to innovate the handwriting examination method connecting tradition and technology.

In this research we do intended to test, with objective data, the relationship between pressure and acceleration in authentic writers, in order to reveal if pressure/speed incongruities can be a forgery warning. Our first is to verify the graphological postulate that declare the correspondence between the increase of speed and the lightening of pressure.

The "Namirial GrafoCerta" software records one movement every 5/ms: nervous system ensures the propagation of spike with the speed of 100/ms so it is possible to measure how many spikes in each signature.

Hypothesis of research

Our goal was to verify if there is a constant correspondence between speed and pressure, if pressure always lightened in acceleration and if it always make heavy in deceleration.

Partecipants.

Twenty one right-handed subject forged their signatures both on-line and on-paper. We asked them to write in three different ways: five signature had be done in their usual speed, five signature decelerating the movement and five speeder. The test had been repeated three times in different days. In total, each person wrote 45 signature on-line and 45 on-paper: in total we have obtained 954 signatures on-line and 954 on-

paper. The order of the signature was randomized to minimize any style effect. No distinctions was made between the partecipants because it did not matter the origin of the handwriting but only its particular dynamic.
For every stroke is revealed length (x) height (y), distance (mm), time (msec), acceleration, pressure (%). The program shows all the overhead movements too: they affect on time but not on pressure.

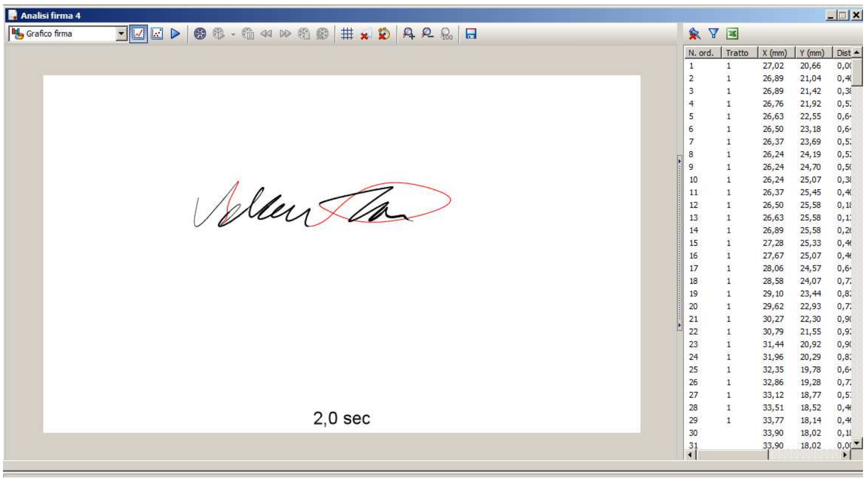

Figure 1: Namirial Software records biometrics values and overhead movements

Materials

On-line signature were done on a Wacom tablet LCD STU-520 Signature tablet (800x480 pixel - electromagnetic resonance technology) and Namirial "FirmaGrafocerta" software. The software convert the pen movement in vectorial data, in format PAdES and created with SHA 256 algorithm.

Procedure

Independent variable was the speed, measured in 5ms. The relative speed was calculated measuring every letter, every break and all the overhead movements. Dependent variable was percentage of pressure.
The Namirial software permit to retrace all the signature in order to individuate the exact point where movement changed direction at the and of one letter and the begin of the following one.
In this way we obtained relatives values of speed and percentage of pressure, finally we add together the relative values to get the global measures.
For illustration we selected, for each person, the signatures with medium-data and we compared the relative and complete measurements of the normal speed, accelerated and decelerated signatures.

Analysis

We found that all people have had more difficulty in slowing their movement rather than accelerating. In all the slowed signature there are more pauses, more fragmentation of shape and more overhead movements, furthermore people put into words their difficulty.
Index of deceleration goes from 3,60% to 84,37%, index of acceleration goes from 6,25 % to 277,97% .

% Speed variation						% Pressure variation				
#	normal	slower	%	faster	%	normal	slower	%	faster	%
1	2240	2570	-12,84	1640	36,59	56,93	86,94	52,71	85,68	50,50
2	2890	5675	-49,07	2720	6,25	69,09	79,47	15,02	92,15	33,38
3	2975	4435	-32,92	2450	21,43	60,87	45,13	-25,86	69,2	13,68
4	3160	20230	-84,38	2815	12,26	75,05	76,93	2,50	75,75	0,93
5	3205	5080	-36,91	2685	19,37	76,31	63,62	-16,63	81,24	6,46
6	3235	4590	-29,52	2565	26,12	75,6	59,73	-20,99	77,43	2,42
7	3280	4440	-26,13	2015	62,78	49,34	46,54	-5,67	46,82	-5,11
8	3335	10365	-67,82	1805	84,76	77,04	91,55	18,83	78,79	2,27
9	3430	7535	-54,48	1850	85,41	70,89	74,52	5,12	85,122	20,08
10	3580	4625	-22,59	3200	11,88	62,33	59,86	-3,96	58,85	-5,58
11	3900	5890	-33,79	1700	129,41	73,92	84,44	14,23	87,66	18,59
12	4310	5285	-18,45	3325	29,62	57,12	68,4	19,75	56,42	-1,23
13	4535	7835	-42,12	3370	34,57	65,29	70,33	7,72	71,38	9,33
14	5015	7055	-28,92	4145	20,99	95,7	88,16	-7,88	94,08	-1,69
15	5725	9855	-41,91	3620	58,15	61,9	76,8	24,07	80,63	30,26
16	6425	6665	-3,60	5400	18,98	60,69	69,96	15,27	63,43	4,51
17	7125	8725	-18,34	5375	32,56	41,08	49,1	19,52	46,77	13,85
18	5920	7430	-20,32	1570	277,07	57,75	48,6	-15,84	61,56	6,60
19	7445	9560	-22,12	6570	13,32	48,2	44,09	-8,53	66,66	38,30
20	7800	10705	-27,14	4555	71,24	58,75	52	-11,49	56	-4,68
21	10455	13970	-25,16	4370	139,24	81,51	82,9	1,71	85,96	5,46

Figure 2: biometrics data

We observed that when speed is reduced 38% of cases (eight on twenty one) there is decrease of pressure with values that goes from -3,96% to -25,86% in all the rest of signatures there is a increase of pressure that goes from +1,71% to 52,71%.

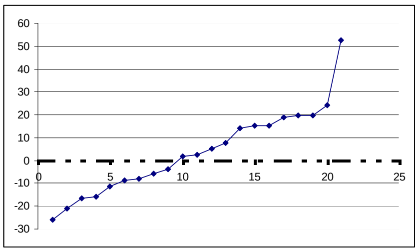

Figure 3: dates of increase/decrease of pressure in slower signature

In 77% of cases (five on twenty one) of speeder signatures pressure increase with a range of variation that goes from 0,93% to 50,50%. In 23% of cases pressure decrease with small values that goes from 1,23% and 5,11%.

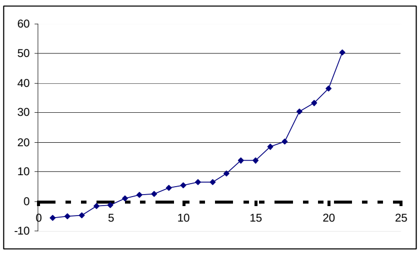

Figure 4: dates of increase/decrease of pressure in faster signature

In particular, we observed that in single signatures pressure tend to increase both in deceleration and in acceleration. In order to illustrate this occurrence, we take the example of signature nr.1: in figure nr 1 the biometrics data, in figure n.2 the results of comparison between the biometrics data where is evident that pressure is less strong only at the beginning of the signature but in the following strokes always increases.

speed (normal)	speed (slower)	speed (fast)	pressure (normal)	pressure (slower)	pressure (fast)
880	870	615	68,05	66,98	62,4
180	95	130	80,09	87,49	87,23
170	295	255	89,37	94,53	95,11
580	460	425	89,8	96,55	94,13
565	355	215	87,36	95,25	89,54
195	260		74,63	80,86	

Figure 5: complete date of signature nr. 1

speed nor/slo	speed norm/fast	speed slowt/fast	pressure nor/slo	pressure norm/fast	pressure slowt/fast
-1,13	-30,11	-29,31	-1,57	-8,30	7,33
-47,22	-27,77	36,84	9,23	8,91	0,29
73,52	50,00	-13,55	5,77	6,42	-0,60
-20,68	-26,72	-7,60	7,51	4,82	2,57
-37,16	-61,94	-39,43	9,03	2,49	6,37

Figure 6: speed and pressure compared data

Conclusions

Handrwrinting expertise found its bases on graphic laws that articulate the rules of the analysis of graphic dynamic. One of the most important correlation is that between speed and pressure and their reciprocal compensation. The finding of higher pen pressure in the modifications of genuine signatures is at odds with the conclusions of Van Galen and Van Gemmert (1996) who found pen pressure to be higher in simulated script.

Although the pen pressure results vary from study to study, one consistent finding is that forging writing

(whether text or signatures) does increase the demands on the processing system and this is reflected in changes to pen movement speed.

For this study we asked to people a particular performance that is to modify the speed on purpose causing a conditions similar to dissimulation.

Data from the present study was subjected to an analysis of movement velocity. In concordance with previous studies it was observed that graphic difficulties are tied to deceleration of speed and that genuine signatures were written more quickly than forged signatures. This finding supports accepted information processing models which suggest that as processing demands increase there is a corresponding movement speed decrease which results from the finite resource allocation properties associated with the cognitive system.

The differences in pen pressure between the forgers' genuine signatures and the forgeries they produced in combination with the non-dependence of the natural signing style of the forger on this change, does indicate that pen pressure can be a useful parameter in discriminating between genuine signatures and forgeries. In order to advance the use of pressure differentials in the forensic environment there is a need to develop pressure measurement techniques.

For a realistic forensic setting with this study we determined pen pressure differentials in genuine signatures simulating disguise.

References

Linton MOHAMMED, Bryan FOUND, Michael CALIGIURI, Doug ROGERS (2009) *Pen Pressure as a Discriminatory Feature between Genuine and Forged Signatures, Proceedings of IGS 2009*

Estabrooks, C. (2000) Measuring relative pen pressure to authenticate signatures. *Journal of the American Society of Questioned Document Examiners, 3*(2), 57-65.

Huber, R., & Headrick, A.(1999). *Handwriting Identification: Facts and Fundamentals.* CRC Press LLC, Boca Raton, FL.

Kam, M., Gummadidala, K., Fielding, G., & Conn, R. (2001). Signature authentication by forensic document examiners.*Journal of Forensic Sciences*, *46*, 884-888.

Lindblom, B., & Seaman-Kelly, J. (2006). *Scientific Examination of Questioned Documents, 2nd. Ed*. CRC Press, Boca Raton, FL.

Mohammed, L., Found, B., & Rogers, D. (2008). Frequency of signature styles in San Diego County. *Journal of the American* Society of Questioned Document Examiners, 11(1), 9-13.

Osborn, A. (1910). *Questioned Documents*. The Lawyers Publishing Co., Rochester, NY.

Schomaker , L., & Plamondon, R. (1990) The relation between pen force and pen-point kinematics in handwriting. *Biological* Cybernetics, 63, 277-289.

Sita, J., Found, B., & Rogers, D. (2002). Forensic handwriting examiners' expertise for signature comparison. *Journal of* Forensic Sciences, 47, 1117-1124.

Sita, J. C., & Rogers, D. (1999). Changes in forgers' handwriting pressure related to the original writer's dynamics. *Journal of Forensic Document Examination*, *12*, 101-112.

Tytell, P. (1998) Pen pressure as an identifying characteristic of signatures: Verification from the computer. *Journal of theAmerican Society of Questioned Document Examiners*, *1*(1), 21-31.

Van Den Heuvel, E., Van Galen, G., Teulings, H.-L., & Van Gemmert, A. (1998) Axial pen force increases with processing demands in handwriting. *Acta Psychologica*, *100*, 145-159.

Van Galen, G., & Van Gemmert, A. (1996). Kinematic and dynamic features of forging another persons handwriting. *Journal ofForensic Document Examination*, *9*, 1-25.