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Quantitative characterization of morphological polymorphism of handwritten characters loops

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Abstract

A methodology based on Fourier descriptors that was previously validated has been applied to 13 writers in order to quantify the polymorphism degree of the shape of the loops of the handwritten characters *a*, *d*, *o* and *q*. In a first step, the discriminating power of the parameters extracted from these letters was investigated. The loop of the letter *d* appeared to be the most discriminant with a correct classification rate of 82.4%, whereas the least discriminant one was the loop of the letter *o* (69.7%). The second aim of the study was to extract grouping characteristics which make it possible to discriminate between writer sets, whatever the letter. Trends in the writing of loops could effectively be shown: the 13 writers of the study were separated into five main groups according to the shape and surface of their loops. The most discriminating features between the writer groups were the importance of the loops elongation and the surface of the loops. Finally, the differences between writers belonging to distinct groups could be characterized more precisely, and differences between writers belonging to the same group were revealed; the individual writings were distinguished by the variability of the parameters of shape and surface of their loops and the morphological distances between its different letters. The correct classification rates reached in this study suggest that carrying out an expertise of fragmentary samples of handwriting comprising only some loops is completely possible.

Keywords: Handwriting; Polymorphism; Shape analysis; Fourier descriptors

1. Introduction

Handwriting examination consists in describing handwriting features, such as elements of style or elements of execution, and studying their range of variation in order to individualize a particular writer through comparison. Characterization of these writing habits as well as the evaluation of the extent of their variability is essentially subjective. Few studies on Roman handwriting were concerned with this lack of objectivity and suggested solutions to provide an objective and quantitative description of writing habits from a forensic point of view. The feature vectors obtained from handwriting documents in previous studies were related to global (based on the handwriting image) [1–4], local (based on zones of interest of the handwriting image, such as lines, words or allographs) [5–12] or both [13,14] aspects of handwriting, but they did not reflect precise visual aspects of handwriting. These studies were merely focused on the development of techniques providing the most accurate identification rates possible, rather than the precise description of handwriting features as they are observed by examiners during the comparison process of handwriting samples.

In a first paper [15], a methodology based on Fourier descriptors was developed, validated and used to precisely characterize and objectively express the within-variability and the between-variability of the parameters of the shape of the loops of handwritten characters *o* in a population of three writers. This procedure was completely new, since the variability of the shape of loops had hitherto been described only in a subjective or partial way [8].

In this further part of the study, the developed methodology has been applied on a larger population of writers to quantify the morphological polymorphism of the loops of the

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handwritten characters *a*, *d*, *o* and *q*. Three main steps were accomplished to describe this polymorphism:

- the discriminating power of the parameters of shape and surface of the loops of the letters *a*, *d*, *o* and *q* was investigated and compared;
- then, the similarity of the loops shape between the writers was evaluated, in order to extract grouping characteristics which make it possible to discriminate between writer sets, whatever the letter;
- finally, the distinctive characteristics of each writing could be described according to the morphological distances between its different letters and the variability of their loops shape and surface parameters.

2. Materials and methods

2.1. Sampling

Approximately 100 individuals of the *Institut de Police Scientifique*, University of Lausanne, filled out five documents, where each document had to be written on a different day. On each one of these documents, they had to write 10 times a series of alphabet letters, in their usual way. Paper (standard blank paper of format A4) and pen (ball point pen Bic® Cristal™ with blue color ink) were provided to each participant. Among the collected samples, only the 13 writers showing closed loops for their characters *a*, *d*, *o* and *q* were retained. The total number of observations was 2325 (591 *a* loops, 547 *d* loops, 596 *o* loops and 591 *q* loops).

2.2. Image analysis procedure/size normalization/Fourier analysis

The extraction of the skeletons of the handwritten loops, as well as the size normalization of these skeletons and the Fourier analysis of their shape, were carried out according to the methodology described in detail in reference [15]. In addition, before normalizing the size of the loops, the surface enclosed in the loops was automatically calculated for each character by means of the Visilog 6.0® software.

2.3. Statistical analysis

S-plus® 2000 (Mathsoft Inc.) and SPSS® 12.0 (SPSS Inc.) were used to analyse the numerical data obtained.

Table 1
Surface and Fourier analysis of the handwritten loops *a* of the writers W1–W13: summary statistics[a] of the surface and the first four pairs of Fourier amplitudes (A_1–A_4) and phases (θ_1–θ_4)[b]

Writer	Statistics	Surface	A_1	A_2	A_3	A_4	θ_1	θ_2	θ_3	θ_4
W1	*X*	0.065	0.06	1.18	0.25	0.25	337.86	64.51	93.38	70.41
	S.D.	0.012	0.01	0.33	0.12	0.12	29.40	11.82	20.02	14.91
W2	*X*	0.072	0.07	0.43	0.23	0.11	337.38	57.51	93.87	72.63
	S.D.	0.012	0.01	0.23	0.12	0.06	25.03	24.14	22.64	17.81
W3	*X*	0.049	0.06	0.57	0.33	0.21	280.07	34.87	73.96	49.12
	S.D.	0.010	0.03	0.30	0.17	0.08	92.56	35.65	19.23	19.04
W4	*X*	0.058	0.11	1.16	0.31	0.27	350.13	66.85	124.56	73.30
	S.D.	0.018	0.04	0.50	0.14	0.18	45.75	24.07	11.18	20.32
W5	*X*	0.037	0.06	2.02	0.18	0.56	308.59	43.18	128.77	44.68
	S.D.	0.006	0.02	0.27	0.08	0.15	78.71	5.86	13.96	5.66
W6	*X*	0.031	0.13	1.92	0.23	0.46	365.94	51.53	115.93	53.33
	S.D.	0.008	0.05	0.41	0.10	0.18	30.28	7.90	14.03	10.84
W7	*X*	0.025	0.13	1.99	0.21	0.51	341.72	51.90	117.78	53.28
	S.D.	0.007	0.05	0.28	0.08	0.13	18.37	6.56	12.51	8.33
W8	*X*	0.028	0.10	1.93	0.21	0.56	358.56	56.45	123.93	57.91
	S.D.	0.005	0.05	0.23	0.10	0.13	37.15	5.92	15.50	5.83
W9	*X*	0.049	0.05	0.55	0.29	0.17	291.06	67.73	76.47	55.49
	S.D.	0.007	0.02	0.23	0.11	0.07	72.84	20.55	13.95	11.26
W10	*X*	0.147	0.08	1.08	0.21	0.20	339.80	83.50	100.65	80.11
	S.D.	0.054	0.03	0.32	0.08	0.09	35.88	8.23	13.83	8.12
W11	*X*	0.078	0.08	0.98	0.19	0.13	351.69	29.29	77.63	38.88
	S.D.	0.021	0.02	0.23	0.08	0.08	33.93	11.30	11.85	21.79
W12	*X*	0.025	0.19	1.70	0.38	0.50	340.52	70.08	97.05	66.98
	S.D.	0.005	0.05	0.26	0.19	0.10	22.81	6.53	9.83	4.75
W13	*X*	0.016	0.14	1.40	0.22	0.28	339.94	72.00	124.35	75.87
	S.D.	0.004	0.04	0.30	0.09	0.11	18.18	8.37	17.78	8.85

[a] *X*, mean; S.D, standard deviation.
[b] Surface is given in cm^2 and phases are given in degrees.