Available online at www.sciencedirect.com
ScienceDirect
Forensic Science International 167 (2007) 163–166
Forensic Science International
www.elsevier.com/locate/forsciint

Max Frei theory revisitation: Does really strokes depth change along time?

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Received 8 June 2006; accepted 14 June 2006
Available online 2 August 2006

Abstract

A serious problem in questioned document examination is to establish the age of written lines. With respect to paper dating, in the past, Max Frei theory (based only on microscope analysis) claimed that strokes are time-dependent. Therefore, according to this theory, it has been asserted that from the analysis of the strokes depth changes it is possible to try to date the handwritten document (to find out that the document is older than . . .). In the present work, we investigate the strokes depth change by a laser profilometer considering not only the time but also microclimatic variations. First, we analyze the stability of stroke characteristics along the time. In particular, we demonstrate that if the document is preserved without change of temperature and humidity, the depth of the strokes has not appreciable changes. In this way, we have the purpose to verify the real possibility of documents dating by means of Max Frei theory. Subsequently, we test how the 3D profile of strokes changes in connection with the microclimatic variations. In particular, we test humidity variations. With this experiment, we show that humidity variations reduce the strokes depth. Moreover, this effect shows a non-linear trend, leaving a hysteresis on the depth.

Finally, we show that the analysis of 3D stroke profile is unable to determine the age of documents.

Keywords: Forensic; Questioned documents; 3D laser profilometry; Topography

1. Introduction

A difficult forensic science problem, in questioned document examination, is to establish the age of written lines. In fact, at the moment, there are no accepted techniques available to allow absolute ink's dating [1], specially because all of them are too sensitive with respect to document storing conditions. Therefore, it is often necessary to utilize other features pertaining to the creation and history of the documents. Because the signature, produced with a pen, is often the only handwritten trace in a questioned document, it represents the most important element to date it.

Handwriting on a common paper sheet it is possible to observe how the pen-tip, besides releasing the ink, deforms the paper. This is because, the writing pressure leaves more or less deep impressions, according to:

- writing pressure (amount of pressure exerted over the paper during the act of writing);
- underlying material (sheet of paper lying on a metal surface or on a paper block);
- writing material (fountain, pencil, ballpoint pen interact in different ways with the paper);
- type of paper used (the production process determines the size and the morphology of the fiber's layers in the paper).

Therefore, three-dimensional analysis of handwriting can be used to have information on stroke impression and on the pressure applied to the paper during writing.

Recently, 3D laser profilometry has been introduced to transform seemingly flat pen strokes into landscapes of hills and valleys [2–4]. The resulting 3D profile shows the pen-tip strokes as an impression in the paper. This method allows measurements in z-axis (uncertainty less than 1 μm) in every point of the map.

With respect to paper dating, in the past, Frei–Sulzer theory (based only on microscope analysis) [5] claimed that strokes are time-dependent, due to the (supposed by his observations) 3-year paper elastic release time. According to this theory, it is

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doi:10.1016/j.forsciint.2006.06.055

possible to try to date the handwritten document studying depth change over the time.

Today, by means of 3D reconstruction of stroke profile, it is possible to verify if the Frei–Sulzer theory is really applicable for documents dating.

In this paper, we investigate the strokes by a laser profilometer considering not only the time but also microclimatic variations.

The paper is organized as follows.

First we analyze the stability of stroke characteristics along the time. In particular we demonstrate that if the document is preserved without change of temperature and humidity, the depth of the strokes has not appreciable changes, within the sensitivity of the used profilometer. In this work, the stability of three-dimensional features is tested along 3 years. It is valid the assumption that the document is preserved with stable microclimatic conditions.

Subsequently, we test how the 3D profile of strokes changes in connection with the microclimatic variations. In particular, we have studied humidity variations. With this experiment, we show that an increase of humidity reduces the strokes depth.

2. Material and methods

To test the stability of stroke characteristics along the time we have performed some different experiments. Firstly, we have made some specimens with six different strokes. Three strokes, approximately rectilinear, have been carried out with different pressure using a ballpoint pen and soft underlying material. The other three strokes have been realized with the same precedent conditions but using hard underlying material. Subsequently, one specimen has been sealed up inside a box (see Fig. 1). In this way, the specimen is preserved without moisture change. Besides, if it is stored with stable temperature, there are not variations of relative humidity. To have the possibility to use a laser, to determine the depth of the stroke, an optical window is present in the box.

In order to vary the writing pressure in an objective and quantified way, an experimental setup as shown in Fig. 2 was constructed. The ballpoint pen is kept in a pen support that is translated, in X–Y coordinates, by means of an electromechanical device. Two kinds of underlying material were considered. On the one hand, the strokes were made on a ''soft'' underground consisting of a pile of 0.1 cm of 80 g/m^2 paper; on the other hand, strokes were made on the ''hard'' underground of a metal plate.

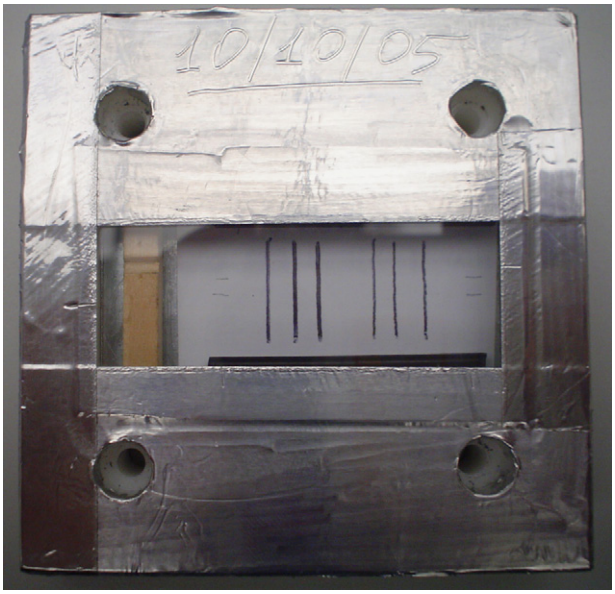

Fig. 1. Box, with optical window. Inside this box is sealed a paper with six strokes.

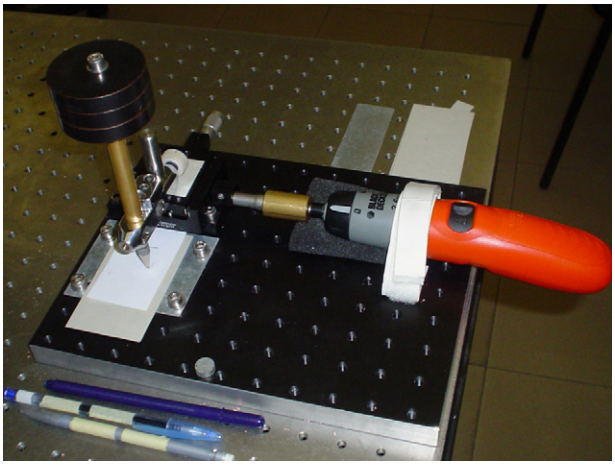

Fig. 2. Experimental setup by means X–Y electromechanical device with the ballpoint pen kept in the pen support.

In order to obtain controlled writing pressure, weights of lead were loaded on the pen support (weights of 250, 500 and 750 g were used). Strokes written with a weight of 500 g were found to have a similar impression as normal handwriting.

The experimental setup and the procedure used to perform the writing are very similar to that proposed in Ref. [3].

To determine the stroke depth, in this work, we propose the use of the 3D laser profilometry, realized by means of the conoscopic holography. It is suitable to obtain 3D micro-topography with high resolution, better than 1 μm in height (z-coordinate), also on surfaces with uneven reflectivity (this situation is usual on the surface of the handwritten document). The technique is able to obtain 3D profiles in non-invading way. Therefore, the system leaves the investigated surface unaltered so that the questioned document can be studied by means of other destructive or non-destructive techniques in different moments, also in the case of forensic analysis with the necessity to preserve the original sample.

A second specimen, made in contemporary to the precedent, is positioned in the laboratory without protection. In this way, it has suffered all microclimatic variations present in the laboratory. It is important to note that the temperature of the laboratory was nearly constant during all experiments (about 22 °C). On the contrary, the relative humidity was variable.

The second experiment, to verify the time stability of strokes, consists to compare the depth of the same strokes measured with a distance, in time, of 32 months.

Finally, to check the humidity effect, other samples (carried out in similar way to the precedents) have been exposed to cyclical variations of humidity (during all the experiments we use constant temperature).

3. Results and discussion

To control the strokes depth stability, along the time, the sealed box was monitored, with 3D laser profilometry, for about 8 months. To avoid the uncertainties of box repositioning, under the laser profilometry, strokes profiles are averaged along the stroke direction (see Fig. 3). Fig. 4 shows the percentage of depth variation versus time. From this graphic, it is possible to affirm that without microclimatic variations the depth of strokes is stable along the time. In this case, the percentage variation of 1.5% corresponds to less of a micron of variation of depth (this variation is less than the sensibility of the used