Available online at www.sciencedirect.com
ScienceDirect
Forensic Science International 164 (2006) 102–109
Forensic Science International
www.elsevier.com/locate/forsciint

Potentiality of 3D laser profilometry to determine the sequence of homogenous crossing lines on questioned documents

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Received 19 July 2005; received in revised form 30 November 2005; accepted 5 December 2005
Available online 20 January 2006

Abstract

The determination of the sequence of line crossings is still a current problem in the field of forensic documents examination. Optical examination, lifting technique, ESDA technique, and electron microscopy are the most widely used methods for the determination of the writing order of crossing texts. However, at present many examinations of intersecting lines result in an inconclusive opinion, particularly if the same type and colour of ink is involved. This paper presents the potentiality of the 3D laser profilometry, which has been to determine the chronological sequence of homogenous "crossing lines". The laser profilometry, illustrated in this paper, has been developed on a conoscopic holography based system. It is a non-contact three-dimensional measuring system that allows producing holograms, even with incoherent light, with fringe periods that can be measured precisely to determine the exact distance to the point measured. This technique is suitable to obtain a 3D micro-topography with high resolution also on surfaces with unevenness reflectivity (usual for the paper surface). The proposed technique is able to obtained 3D profile in non-invading way. Therefore, the original draft are not physically or chemically modified, allowing a multi-analysis in different times. The experiments performed with line crossings database show that the proposed method is able of "positive identification" of writing sequence in the majority of the tests. In absence of a positive identification, the result has been "inconclusive" (no false determination did occur in this work).

Keywords: Forensics; Questioned documents; 3D laser profilometry; Topography; Crossing line; Determination of writing sequence

1. Introduction

Even with the advent of electronic communication, electronic signatures and a whole array of electronic business transactions, the paper based document remains widely used and trusted for any business and legal documents. Besides, the problem of forgery remains an ever present problem and is still of great interest in forensic science. There are occasions when documents used in criminal activities or in the course of civil litigation are either altered or created specifically for the purpose of deception.

A difficult problem in questioned document examination is the determination of the order of crossed line.

The determination of the order of crossing lines is appropriate in cases of suspicions that the content of a document has been altered at a later date by adding a part to it, for instance in a will or signed legal agreement (blank signature). Therefore, the determination of sequence of crossing strokes [1–3] can provide important information when investigating fraud.

A variety of techniques can be employed to view an intersection. Optical examination, lifting technique, ESDA technique, and electron microscopy are the most widely used methods for the determination of the writing order of crossing texts. Unfortunately, many examinations of intersecting lines result in an inconclusive opinion, particularly when two inks are similar in colour and composed of the same type of ink. For these reasons, one of the most appealing challengers for questioned document examiners is the improvement of techniques, which can be used for determination of sequence of lines of homogenous intersection (crossing lines made by the same type of ink or media).

Handwriting on a common paper sheet allows to observe how, the pen-tip, besides releasing the ink, deforms the paper. In other words, the writing pressure leaves some impressions; several or less deep ones according to:

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0379-0738/$ – see front matter
doi:10.1016/j.forsciint.2005.12.004

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

Therefore, a three-dimensional analysis of handwriting gives information on stroke sequence and on the pressure applied to the paper during writing, so as pen-up (stroke end vertex) and pen-down (stroke start vertex). The process of writing on a common paper sheet is similar to the writing on the sand (the paper sheet, for the writing, behaves as plastic material).

In Fig. 1 we see two eight drawn on the sand. The writing dynamics of two different 'eight' symbols is evident. The second stroke, when crosses the first stroke, modifies the produced groove in the sand according to the object used for the writing. In particular, it is possible to note the presence of some 'bumps' along the first stroke. These bumps are located at the sides of the second stroke that crosses the first one. The presence of these irregularities is localized in the strokes' crossing zone, along the first stroke line.

In this paper, we propose the use of the 3D laser profilometry, realized by means of the conoscopic holography, to transform seemingly flat handwritten letters into landscapes of hills and valleys that reveal the pressure and stroke sequence used to create each word documents. Conoscopic holography is a non-contact three-dimensional measuring technique that makes possible to produce holograms, even with incoherent light, with fringe periods that can be measured precisely to determine the exact distance to the point measured. It is suitable to obtain 3D micro-topography with high resolution also on surface with unevenness reflectivity (this situation is usual on the surface of the handwritten document). The technique is able to obtained 3D profile 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 technique in different time, also in case of forensic analysis with the necessity to preserve the original sample.

The determination of the 3D micro-topography, in the field of forensic document examination, can be obtained using the scanning electron microscope (SEM) [4,5] or atomic force microscopy [6]. SEM and AFM are promising 3D-techniques, but have a limited range in the vertical direction ($\sim$5 μm) and in the scanning area ($<$2 cm^2); while by means of laser profilometry a 3D micro-topography overcoming the limits imposed by the use of the techniques SEM and AFM is possible. In fact, with the laser profilometry technique non-destructive examination of ''wide'' zones of documents can be made.

The 3D laser profilometry has been introduced, as a useful tool for the examination of crossing lines, in Refs. [3,7]. The aim of this paper is to study the potentiality of this method and, despite of complicating inhomogeneous structure of the paper and the writing impression, determine the writing sequence when the inks are chemically and optically mixed at the crossings (homogenous crossing lines).

This paper is organized as follows: in Section 2, the conoscopic holography and used conoscopic range finder are briefly described. In Section 3, the proposed method is described and the experimental results are presented. The conclusions are presented in Section 4.

2. Conoscopic holography and conoscopic range finder

A conoscopic range finder (based on conoscopic holography) is well suited to provide an accurate 3D profile of handwritten documents. At present, cheap conoscopic systems, well adapted to work in the field, are available.

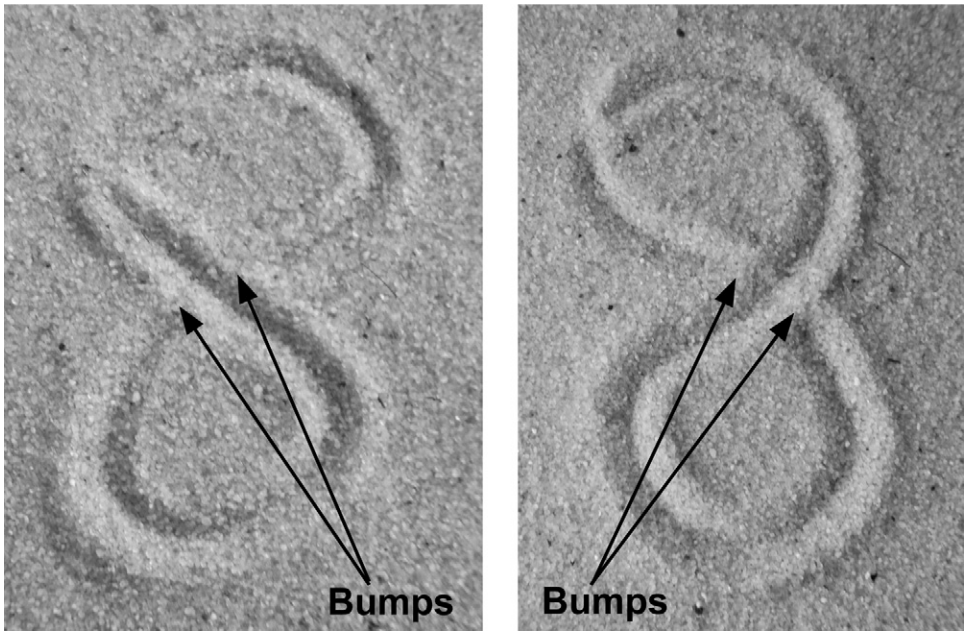

Fig. 1. Eight drawn, with different dynamics, on the sand.