FORENSIC EXAMINATION OF INDENTED WRITING IMPRESSIONS IN QUESTIONED DOCUMENTS BY FLATBED SCANNERS

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Abstract: The application of science in analyzing the questioned documents is termed the forensic document examination. The writing indented impressions in the underlaying paper sheets can be revealed either primarily using an angled, oblique high intensity light or more efficiently by the Electrostatic Detection Apparatus (ESDA). However, because of the limited budget in Thailand, the availability of the ESDA in police crime labs nationwide is inadequate. This suggests that an instrument with comparable performances and cheaper price should be an alternative. In this research, indented writing impressions made in various types of paper commonly found in crime investigations were examined using both ESDA and commercial flatbed scanners with an image enhancement software (Adobe Photoshop CS6). Methodology was divided into three experiments: Test 1: Variation of interleaving paper, Test 2: Paper Quality and Test 3: Variation of writing pressure. Results obviously show flatbed scanners can be used as an ad-hoc and alternative instrument for recovery and revealing indented writing impressions.

Introduction: Indented impressions of handwriting are invisible marks pressed into the paper surfaces when one document is written out while resting on the top of another page. The writing on the underlaying pages primarily can be revealed by several means [1]. Currently, the most efficient way to recover the indented impression is to use Electrostatic Detection Apparatus (ESDA). The apparatus has been successfully implemented in the investigation of the questioned documents for several decades. However, in Thailand, the availability of the instrument, in police crime labs nationwide, is rather limited due to their high costs. This suggests that, if possible, an instrument with comparable performances and cheaper price should be an alternative. In recent years, office scanner and simple image enhancement software have been studied to be an alternative instrument for the indented impression recovery. An interesting work performed by S J Starch [2] and Brown S., et al. [3] showed the possibility of using office scanners and imaging enhancement software to reveal indented impressions in paper. In this study, more experimentation on the performances of flatbed scanners to recover the indented writing impression in paper was conducted. The performance examinations included the investigations of the scanner recovery performances in terms of (1) the variation of interleaving paper, (2) the paper quality and (3) the variation of writing pressure. Two types of the flatbed scanners based on different image sensors; i.e. charged couple device (ccd) and contact image sensor (cis) scanners were used. Their scanned images were compared in terms of clarity and contrast against images obtained from ESDA. These extended works were conducted with an intention to show whether the flatbed scanner can be used as an ad-hoc and alternative instrument for recovery and revealing indented writing impressions.

Methodology: The methodology of this study can be summarized diagrammatically as in Fig. 1. In this study, the writing impressions were created on various types of paper such as 80 g/m^2 A4 office paper and glossy paper. A ballpoint pen was used to write the words “INDENTED IMPRESSIONS FOR ESDA” on a paper top sheet while the *three* underlaying sheets used in the process of recovery were the same paper type. Note that, the chosen words

contain major strokes, such as horizontal lines, vertical lines and diagonal lines, normally found in letters. Then, the recovering process of the indented writing impression from paper sheets beneath the top one were conducted using both ESDA and flatbed scanners. The ESDA DOCUSTAT DS-210 manufactured by Projectina was firstly used to recover the writing impressions and its results were used as references for comparison with the recovered impressions made by scanners. Two flatbed scanners with different image sensors were used. HP scanjet 2300c employs the charged coupled device or ccd as its image sensor while CanoScan LiDE 700F uses the contact image sensor (cis) as its image sensor. The scanned images were carried out both in grayscale and color modes. To enhance the clarity and contrast of the scanned impression images, image enhancement functions such as image function and unsharp function in the Adobe Photoshop CS6 were used. Each image was scanned in two orientations and subsequently the scanned images were combined with a viewing function in the Adobe Photoshop CS6 program. The contribution from each scanned image should improve the clarity and contrast of the image of the writing impression.

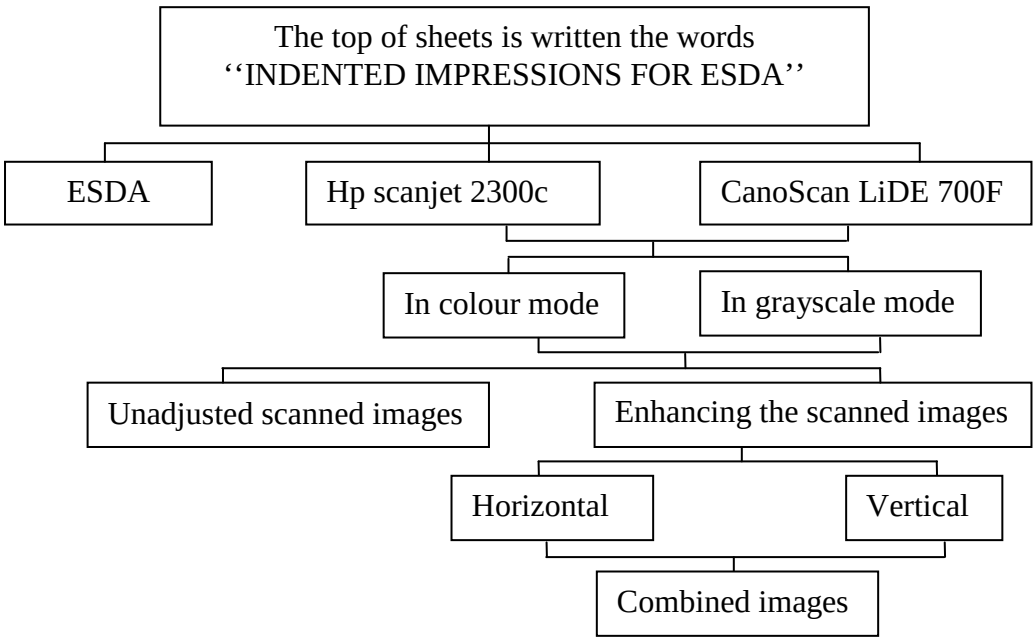

Fig. 1 Diagram of experimental procedures for recovering the indented writing impressions by ESDA and flatbed scanners.

Experiments: Tests corresponding to three conditions were proposed to examine the performances of the flatbed scanners. The assessment could be done by a direct comparison in terms of clarity and contrast between the ESDA images and scanned images obtained from the flatbed scanners. Test 1 : “the variation of interleaving paper” is designed to investigate the number of legible images obtained from the recovery of indented writing impressions from interleaving office A4 paper. Test 2 : “the paper quality” is designed to investigate the number of legible images obtained from the recovery of indented writing impression from interleaving glossy paper and Test 3 : “the variation of writing pressure” is designed to investigate the effect of the writing pressure on various types of paper for the recovery of indented writing impression. The result evaluation was a qualitative measurement. The experimental results were reported as four levels: clearly readable, hardly readable, visible (illegible) and not visible.

Results: By following the procedures described in the diagram (Fig. 1), ESDA was firstly used to recover the indented writing impression from underlaying sheets for all tests. The images obtained were used as references for comparison with the corresponding scanned images from HP scanjet2300c and CanoScan LiDE 700F.

Test 1: Variation of interleaving paper

In this test, ESDA could recover the indented writing impressions from all three underlaying sheets. Then, the three underlaying sheets of 80 g/m^2 of A4 paper were brought to scan by Hp scanjet 2300c and Canoscan LiDE 700F in a grayscale mode with a resolution of 300 dpi (dots per inch) in two directions: vertical and horizontal. The scanned images of the underlaying sheets were adjusted by imaging enhancement software (Adobe Photoshop CS 6) using the image function and unsharpen function. The experimental results of the recovered images are shown in Fig. 2.

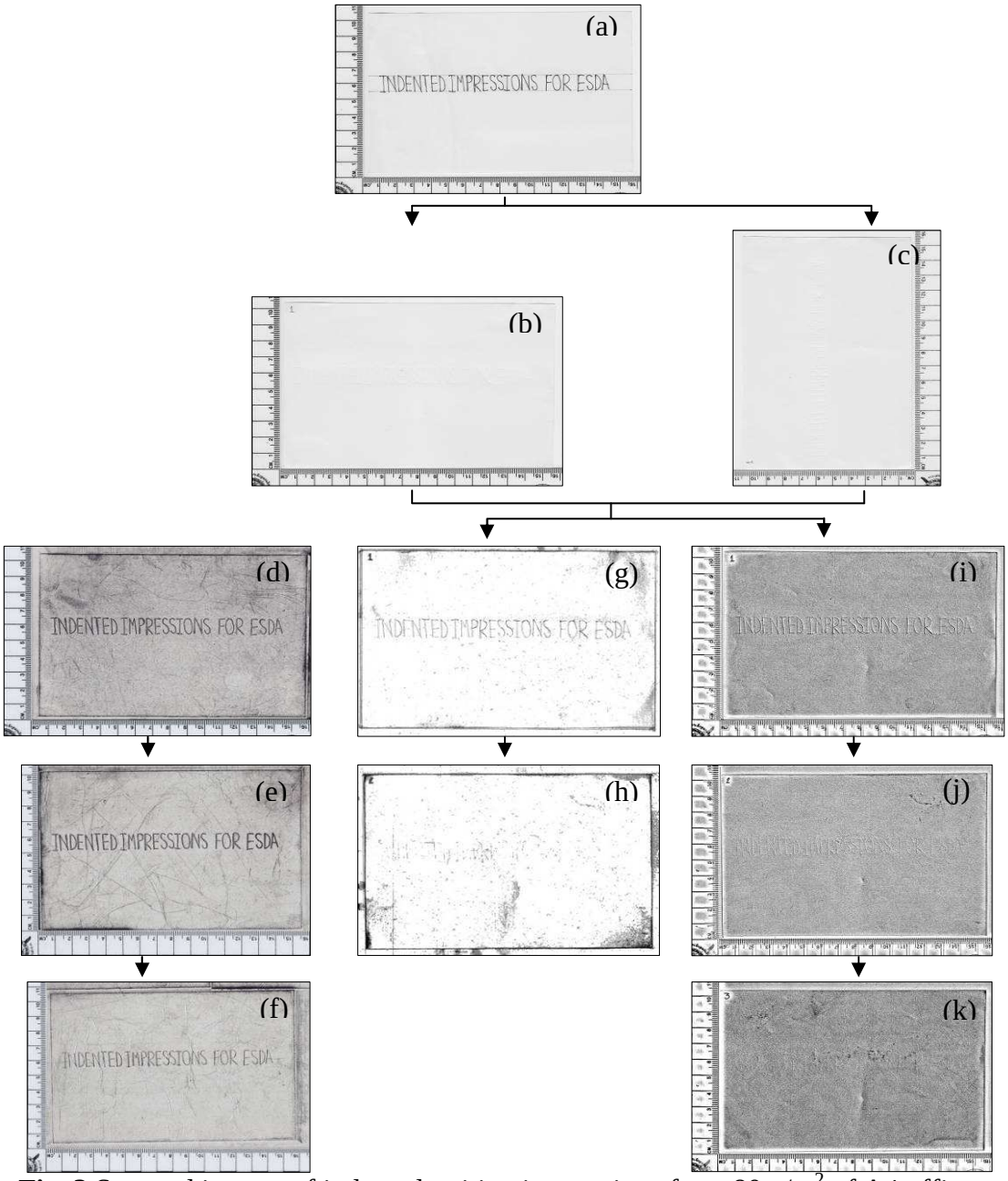

Fig. 2 Scanned images of indented writing impressions from 80 g/m^2 of A4 office paper (a) original writing on the top sheet, (b) and (c) examples of unadjusted scanned images in horizontal and vertical orientations, respectively, (d),(e) and (f) ESDA images of the three

underlaying sheets, (g) and (h) combined enhanced images from Hp scanjet 2300c of the 1st and 2nd underlaying sheets, respectively, (i), (j) and (k) combined enhanced images of CanoScan LiDE 700F of the 1st , 2nd and 3rd underlaying sheets, respectively.

The recovered images from ESDA for all 3 underlaying sheets of indented writing impressions were clearly readable. For the horizontal and vertical combined images scanned by HP scanjet 2300c, the 1st underlaying sheet was readable and the indentation of the 2nd underlaying sheet was visible but illegible. On the 3rd underlaying sheet, the indentation was not visible (not shown here). The scanned images from CanoScan LiDE700F gave the results of readable indentation on the 1st underlaying sheet. On the 2nd underlaying sheet, the recovered indentation was hardly readable and on the 3rd underlaying sheet, the indentation was visible but illegible.

Test 2: Paper Quality

Again, ESDA could recover indented writing impressions from all three underlaying sheets. The underlaying sheets of the glossy paper were scanned by two scanner – Hp scanjet 2300c and Cannoscan LiDE 700F in a grayscale mode with a resolution of 300 dpi in two directions: vertical and horizontal. The images of the underlaying sheets were adjusted by imaging enhancement software (Adobe Photoshop CS 6) using the image function and sharpen function. The experimental results of sample images are shown in Fig. 3.

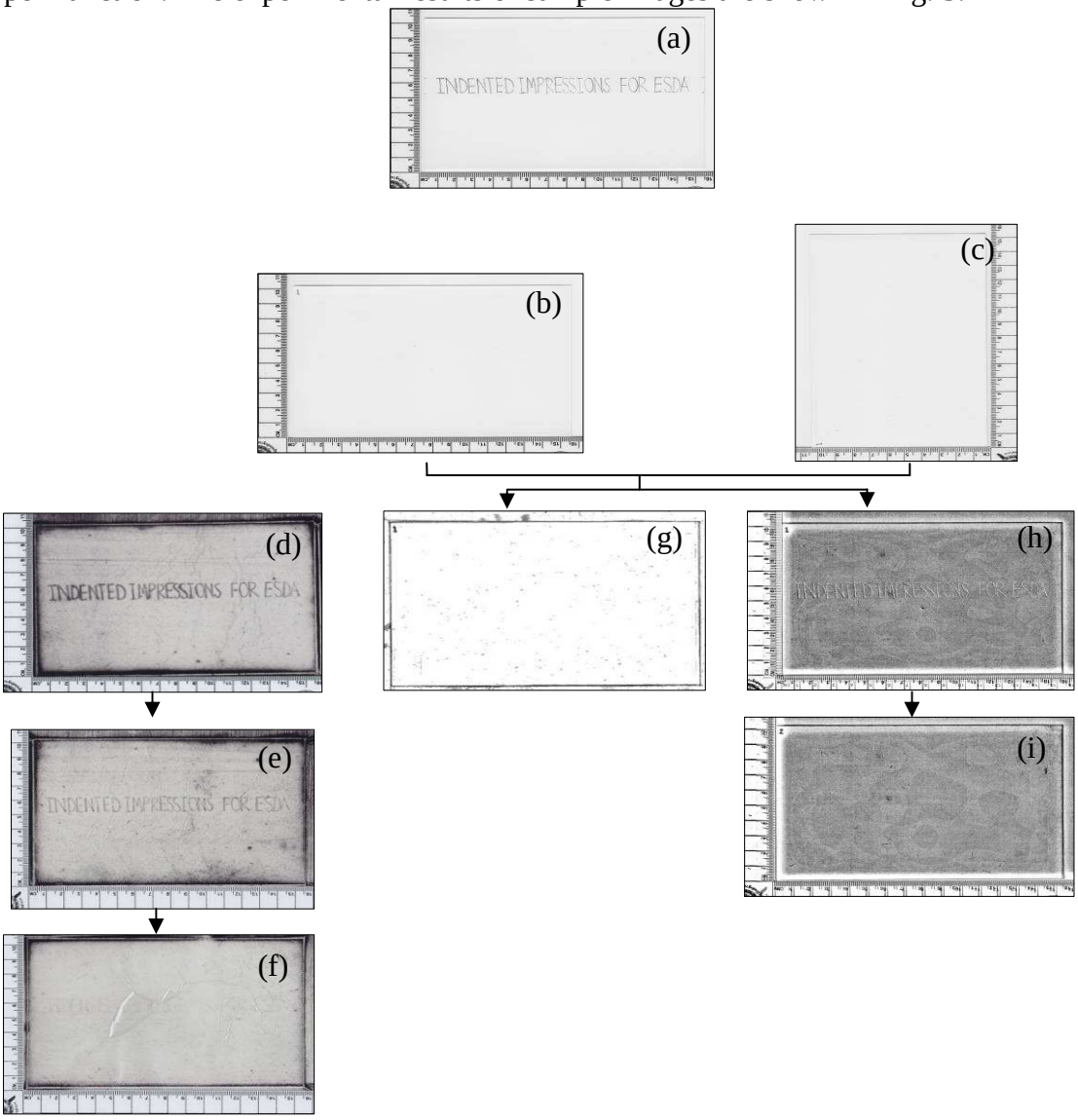

Fig. 3 Scanned images of indented writing impressions from glossy papers (a) original writing on the top sheet, (b) and (c) examples of unadjusted scanned images in horizontal and vertical orientations, respectively, (d),(e) and (f) ESDA images of the three underlaying sheets, (g) combined enhanced images from Hp scanjet 2300c of the 1st underlaying sheets, (h) and (i) combined enhanced images of CanoScan LiDE 700F of the 1st , 2nd underlaying sheets, respectively.

All 3 layers of indented writing impressions could be recovered by ESDA. The recovered images on 1st and 2nd underlaying sheets were readable. The image recovered on the 3rd underlaying sheet was visible but hardly readable (only 1st underlaying sheet shown here). The scanned images of three under laying sheets from HP scanjet 2300c were not visible. Canon LiDE700F could recover the readable indentation only on the 1st underlaying sheet.

Test 3: Variation of writing pressure

An average writing pressure obtained from thirty volunteers writing the statement "INDENTED IMPRESSIONS FOR ESDA" in A4 paper was found to equal to 0.38 N with the standard deviation of 0.16 N. This suggested three magnitudes of writing pressures to be examined. They were (1) light writing pressure of 0.22 N (2) medium or normal writing pressure of 0.38 N and (3) heavy writing pressure of 0.54 N. All three pressure levels were monitored by a force sensor and applied for writing on fifteen types of paper such as deposit slip, cash bill, lease agreement document and newspaper. Fifteen types of papers were scanned by Cannoscan LiDE 700F in a grayscale mode and colour mode with a resolution of 1200 dpi in two directons: vertical and horizontal. The images of the underlaying sheets were adjusted by imaging enhancement software (Adobe Photoshop CS 6) using the image function and sharpen function. Again, ESDA gave good recovered images showing that heavy writing pressure could reveal the indented impressions more than light writing pressure and normal writing pressure. The recovered images from the flatbed scanners also gave similar results. The results of this test are shown in Table 1.

Discussion: For Test 1 and Test 2, ESDA could reveal the indented writing impressions from all three underlaying sheets. CanoScan LiDE 700F, could recover the indented impressions on both A4 paper, 80 g/m^2 and glossy paper, 200 g/m^2. HP scanjet 2300c could recover the indented impression only in A4 paper, 80 g/m^2. The main reason for the different results from two selected scanner is the technological structure for the scanning system. The cis or scanner with the contact image sensor, CanoScan LiDE 700F, gave the better results than ccd, charge coupled device scanner, HP scanjet 2300c. In test 3, the variation of writing pressure, Table 1 shows the results of number of underlaying sheets that could be revealed by ESDA and scanner. The scanner could recover the heavy pressure indented impressions on calendar but ESDA could not. However, the scanner could recover the indented writing impressions on most of selected examples. The numbers of underlaying sheets that indented impression could be recovered for heavy, normal and weak writing force were descending respectively.

Conclusion: The experimental results indicate the possibility of using a commercial scanner and image enhancement software as an alternative instrument for the recovery of the indented writing impression in paper. The numbers of underlaying sheets negatively correlate with the revealed indented impression images made by flatbed scanners. Types of paper have influence in revealing the images. Paper that is thin, no glossy and no pattern are easier in finding the indented impressions. Writing pressure can also affect the legibility of the recovered impression images. Interestingly, the flatbed scanner with the contact image sensor or cis gives legible results in terms of enhancing the writing impressions. The key feature of

the cis scanner should rely on the integration of light sources and image sensor into a single module and being in close contact to the paper sample**.**

Table 1. Experimental results of the number of the underlaying sheets that could be revealed by ESDA and scanner (CanoScan LiDE 700F) reported as visible and not visible

No.	Types of paper	ESDA			Scanner		
		Heavy	Normal	Weak	Heavy	Normal	Weak
1.	Write paper 50 g/m^2	8	6	4	3	2	1
2.	Write paper 60 g/m^2	6	5	4	2	2	1
3.	Write paper 70 g/m^2	3	2	2	2	1	1
4.	Write paper 80 g/m^2	4	2	2	1	1	1
5.	Write paper 120 g/m^2	2	1	1	1	-	-
6.	Brown paper	1	1	1	-	-	-
7.	Siam Commercial Bank deposit slip	5	3	2	1	1	-
8	Siam Commercial Bank transaction record	3	3	3	2	1	1
9.	Cashsale bill	3	3	2	1	1	1
10.	Cover page of the Seventeen magazine	-	-	-	-	-	-
11.	Normal page of the Seventeen magazine	3	2	-	1	-	-
12.	Calendar	-	-	-	1	-	-
13.	White envelope	2	1	1	1	-	-
14.	Lease Agreement	4	3	3	2	1	1
15.	Thairath newspaper	6	5	2	1	1	-

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Keywords: The Electrostatic Detection Apparatus, writing indented impressions, flatbed scanner, imaging enhancement software